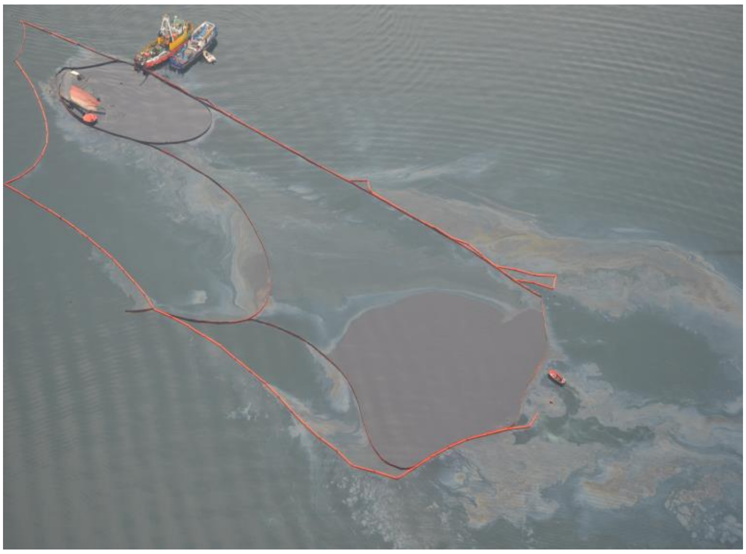
Guide for Combating Accidental Marine Pollution in the Mediterranean Sea

MEDITERRANEAN ACTION PLAN (MAP)
REGIONAL MARINE POLLUTION EMERGENCY RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)



INTERNATIONAL MARITIME ORGANIZATION

UNEP-PNUE

REGIONAL MARINE POLLUTION EMERGENCY

RESPONSE CENTRE FOR THE MEDITERRANEAN SEA (REMPEC)

MEDITERRANEAN ACTION PLAN

Guide for Combating Accidental Marine Pollution in the Mediterranean Sea

Regional Information System

www.rempec.org

October 2000

Note

This document is aimed at facilitating the implementation of the “Protocol concerning Co-operation in Combating Pollution of the Mediterranean Sea by Oil and Other Harmful Substances in Cases of Emergency” of the Barcelona Convention (Emergency Protocol, 1976) and the “Protocol concerning Co-operation in Preventing Pollution from Ships and, in Cases of Emergency, Combating Pollution of the Mediterranean Sea” (Prevention and Emergency Protocol, 2002) by the Contracting Parties of the Barcelona Convention.

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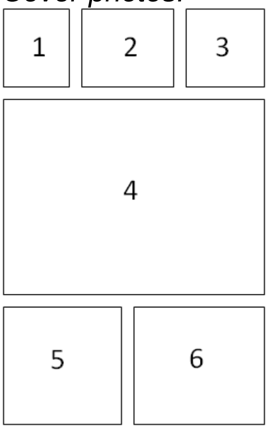

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For bibliographic purposes this document should be cited as follows:
IMO/UNEP: Regional Information System - Operational Guides and Technical Documents - Guide Combating Accidental Marine Pollution in the Mediterranean Sea, REMPEC, October 2000.

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Chapter 1

GENERAL NOTIONS ON OIL SPILLS AND SAFETY CONSIDERATIONS

1. OIL – GENERAL INFORMATION

In the terminology used in the field of marine pollution response the word "oil" is used for both crude oils and any refined products obtained by its distillation. "Oil" thus encompasses various mixtures of chemical compounds consisting mainly of carbon and hydrogen, which chemists call "hydrocarbons", although some other organic and inorganic compounds that are not hydrocarbons also form part of crude oils and petroleum derivatives. Percentages (in weight) of carbon and hydrogen respectively in different crude oils produced in the world, vary between 83 to 87% for carbon and between 11 and 14% for hydrogen. The amounts of other elements are minor, except for sulphur which can reach up to 8% (Iraq). The total number of chemical individualities in a crude oil ranges between 10^5 and 10^6 and most of them are found in heavy fractions. It cannot be expected to have a detailed and precise knowledge of each component of a certain crude oil or refined product.

Three series of hydrocarbons constitute at least 95% of all crude oils:

ALKANES (PARAFFINS):

Series of stable, saturated organic compounds containing chains of carbon atoms linked with only single carbon-carbon bonds and with attached hydrogen atoms. Chains may be straight or branched. General formula: $C_n H_{2n+2}$

CH_4	methane
$C_2 H_6$	ethane
$C_3 H_8$	propane
$C_4 H_{10}$	butane ...

With an increase of the number of carbon atoms in a molecule, the boiling point is increased and volatility is decreased.

CYCLOALKANES (NAPHTENES):

Series of saturated hydrocarbons, similar to alkanes but with ends joined to form a ring structure. Carbon-carbon bonds are single. Some hydrogen atoms may be replaced by other elements such as nitrogen, oxygen or sulphur. General formula: $C_n H_{2n}$

$C_3 H_6$ cyclopropane
$C_5 H_{10}$ cyclopentane

AROMATICS:

Series of organic compounds characterized by benzene ring(s) of 6 carbon atoms with 3 double carbon-carbon bonds. Low boiling aromatics are responsible for toxicity of most oils. Higher boiling aromatics, especially multi-ring compounds are suspected as long term poisons and some of them are known carcinogens.

Another two groups of chemical compounds that are present in crude oils are:

ASPHALTENES:

A series of compounds with very high molecular weights (100 000 and more) and unprecise definition. Very often their structure is unknown. They can be defined as very high boiling solid tars. They contain sulphur, nitrogen and oxygen, as well as metals such as nickel and vanadium.
RESINS:

A group of heterocyclic molecules, containing one or more atoms of oxygen, nitrogen or sulphur. Presence of this heteroatom in their structure causes their slightly surface-active properties which are responsible for initial formation of reverse emulsions with sea water.

The contents of the above-mentioned classes of organic compounds vary from one crude oil to another.

Table 1. Contents of main groups of organic compounds in crude oils

GROUP OF COMPOUNDS		**PERCENTAGE OF WEIGHT**
ALKANES (PARAFFINS)	SATURATED HYDROCARONS	30 - 70 %
CYCLOALKANES (NAPHTENES)		
AROMATICS		20 - 40 %
ASPHALTENES		0 - 10 %
RESINS		5 - 25 %

According to the predominance of one or more classes, crude oil can be classified as follows:

- Paraffinic
- Naphtenic
- Paraffinic / naphtenic
- Paraffinic / naphtenic / aromatic
- Naphtenic / aromatic
- Naphtenic / aromatic / asphaltic
- Aromatic / asphaltic

Toxicity of the above mentioned groups increases along the series:

ALKANES < NAPHTENES < ASPHALTENES < AROMATICS

Within each series of hydrocarbons, the smaller molecules are more toxic than the larger ones.

Lastly it should be mentioned that there is another series of hydrocarbons which cannot be found in crude oils but is common in refined products:

ALKENES (OLEFINS):

Series of unsaturated, non-cyclic hydrocarbons which contain at least one double bond between carbon atoms. Chains may be straight and branched. As a result of their higher reactivity, alkenes are probably more toxic than alkanes.

1.1 Characteristics of Crude Oil

Crude oils are liquids ranging in colour from light amber to opaque black (asphalthenic crudes). They can have green (paraffinic) or blue (naphtenic) fluorescence. Their smell is unpleasant due to the presence of sulphureous compounds.

Their viscosity varies as a function of light fractions content. They are highly inflammable (flash points less than 30 °C).

Their specific gravity varies between 0.750 (paraffinic crudes) and 1.06.

Before transportation, crude oils are dehydrated and stabilized in order to remove incondensable and nauseous gases, water and impurities.

Following their spillage on sea, oils are subject to various physico-chemical changes, depending on their nature as well as on oceanographic conditions. These changes will influence a great deal the selection of oil combating techniques to be used.

Table 2. Properties of crude oils

CATEGORIE CATEGORY	PAYS/ COUNTRY	TYPE	DENSITE/ SPECIFIC GRAVITY	VISCOSITE [CsT]/ VISCOSITY	POINT D'ECOULEMENT [ºC] POUR POINT
1. *Haute tenur en parafineres* High paraffin content	EGYPTE/EGYPT GABON/GABON LIBYE/LIBYA NIGERIA/NIGERIA	El Morgan Gamba Es Sider Nigerian Light	0.874 0.872 0.841 0.844	**à/at 38ºC** 13 28.5 5.7 3.6	13 30 9 21
2. *Tenur en paraffines moyenne* Average paraffin content	QATAR/QATAR RUSSIE/RUSSIA ALGERIE/ALGERIA LIBYE/LIBYA IRAN/IRAN IRAQ/IRAQ ABU DHABI/ ABU DHABI NORVEGE/NORWAY	Qatar Romaskinskaya Zarzaitine Brega Zueitina Iranian Light Iranian Heavy Northern Iraq Abu Dhabi A.D. Zakum A.D. Umm Shaif Ekofisk	0.814 0.859 0.816 0.824 0.808 0.854 0.869 0.845 0.830 0.825 0.840 0.847	**à/at 10ºC** 4.5 20 9 6.3 5 20 30 9 6.2 5 6.5 9	-18 -4 -15 -18 -12 -4 -7 -15 -18 -15 -15 -4
3. *Faible tenue en paraffines* Low paraffin content	ALGERIE/ALGERIA NIGERIA/NIGERIA KOWEIT/KUWAIT ARABIE SAUDITE/ SAUDI ARABIA IRAQ/IRAQ OMAN/OMAN VENEZUELA/ VENEZUELA	Hassi Messaoud Arzew Nigerian Medium Nigerian Export Kuwalt Arabian Light Arabian Medium Arabian Heavy Southern Iraq Oman Tia Juana Medium	0.802 0.809 0.907 0.872 0.869 0.851 0.874 0.887 0.847 0.861 0.900	**à/at 10ºC** 3 4,3 60 13 30 12 29 80 13 25 70	<-30 <-30 <-30 <-30 -18 <-30 -15 <-30 -13 -8 <-30
4. *Très faible tenur en paraffines (très visqueux)* Very low paraffin content (very viscous)	VENEZUELA/ VENEZUELA	Bachaquero Tia Juana pes	0.978 0.980	**à/at 38ºC** 1280 2980	-7 -3

Table 3. Properties of various refined products

CATEGORY	NAME	DENSITY at 15ºC	LIMIT OF DISTILLATION [ºC]	VISCOSITY	FLASH POINT [ºC]	POUR POINT [ºC]
1. LIGHT PRODUCTS	Condensates		40-140		< 0	
	Naphtas		70-165		< 0	
	Spécial boiling point gasoline	0.65-0.75	40-160		< 0	
	Aviation gasoline's	0.75	60-200		< 0	
	Automotive gasolines	≤ 0.77	60-210		< 0	
	White spirit		135-205		> 30	
2. INTERMEDIATE PRODUCTS	Jet fuels	0.80-0.82	180-260		> 38	
	Kerosene	0.80-0.82	180-260		> 38	
	Lamp oil	0.80-0.85	200-285		> 38	
	Home heating oil	0.80-0.90	200-380	< 9.5/20 ºC	> 55	< - 9
	Diesel oil	0.81-0.89	250-360	< 9.5/20 ºC	> 55	< - 12
	Light marine diesel oil	0.81-0.89	250-360	< 9.5/20 ºC	> 60	< - 6
	Straight-run gas oil	0.84-0.87	250-380	< 9-15/50 ºC		
3. HEAVY PRODUCTS	Mineral oils		200-400	20-200/50ºC		
	Lubricating oils		200-400	20-200/50ºC		
	Straight-run fuel oils		250-500			
	No.5 Fuel oils *(Fiouls No.1)*		250-500	15-110/50ºC	> 70	
	No.6 Fuel oils *(Fiouls No.2)*		350-500	110-600/100	> 70	
	Paraffin, wax		200-400	9-45/100 ºC	> 180	
	Bitumen		350-500		> 230	Softening Point 35-65
	Asphalt		350-500		> 230	

Note: All temperatures in degrees Centigrade / All viscosities in centiskokes (kinematic viscosity)
Absolute viscosity = viscosity x density)

2. IDENTIFICATION OF A POLLUTANT

The reasons for analysing physical and chemical characteristics of spilled oil may vary. In case of a massive accidental spill, the source is usually known and the results of analyses will mainly serve to predict the behaviour and fate of spilled oil and to enable selecting the most adequate response methods and materials. On the other hand, in case of a deliberate discharge of oil (which may also be of significant size and have serious consequences) the source is most often unknown. In such cases the analysis of the sample(s) will, besides the above two mentioned purposes, primarily serve to help in identifying the source of pollution and to provide necessary evidence for the prosecution of offenders. However, the identification of the source of pollution through samples taken at sea or on shore may be accepted as a sufficient legal evidence, only providing that a sample of suspected cargo or oil from the machinery space is also available or, in case of crude oil cargoes, at least that its origin is known.

The possibility of legal proceedings at the later stage, that might necessitate presenting results of sample analyses as evidence to the court, should always be borne in mind in cases of both accidental and deliberate discharges.

2.1 Sampling

If reliable results are expected from analyses, a special attention should be paid to sampling. Taking samples of the pollutant should not present a serious problem when there is a sufficient quantity of pollutant, that is, when the oil layer is thick. In such a case, the only factor to be considered is cleanliness of containers in which samples are taken. More problems arise when the pollutant is spread in a very thin layer. However these can be overcome by using purposely designed sampling devices such as sorbent cartridges, special sponges, etc...

Sufficient quantity for necessary analyses will rarely exceed 250 ml. In all cases, samples should be kept in glass or metal containers since certain plastic materials may react with hydrocarbons. The samples should be taken immediately after the spill becomes known, properly labelled (location, date, time ...) and sealed in the presence of witnesses. Bearing in mind possible legal actions, a part of the sample (besides the one sent for analysis) should be stored and conserved (if possible, at approximately 5°C) until the results of analysis are justified in court.

2.2 Determination of oil characteristics

Although not sufficient for identification of the pollutant (nature, origin) determination of principal physical and chemical characteristics may greatly facilitate decision-taking process in spill response operations. If the quantity of sample permits, physical characteristics of oil such as viscosity, density and pour point can be tested. Classic methods of analytical chemistry can be used to determine, for example, wax, asphaltene, sulphur and nitrogen contents. Knowledge of some of these characteristics will on one hand help predicting the movement of oil, rate of emulsification, sinking, etc ..., while on the other hand it will suggest using certain clean-up techniques and eliminating the others (for example, too high viscosity will automatically exclude the possibility of using dispersants and certain types of skimmers and pumps).

Identification of an oil pollutant is carried out in order to determine as precisely as possible the nature and the origin of spilled oil. Comparing the results of pollutant analysis with the results obtained by analysing sample(s) taken from suspected source(s), the offender can be established and prosecuted.

The methodology of identifying an oil pollutant comprises preliminary phases of sample treatment and a series of dosages and subsequent analyses.

Preliminary treatment of samples consists of:

- Separating oil from water, solid debris and sediments by organic solvent extraction;
- Evaporating and concentrating the extract;
- Preparing a distillation residue at a defined temperature (e.g. 300C) in order to bring all the samples in the same physical condition, regardless of their state of weathering.

A certain number of determinations is then made on this residue which, in the most simple cases, comprise:

- measuring organic sulphur contents;
- measuring nickel and vanadium contents, because their ratio, which is a characteristic of crude oils origin, does not change with time spent at sea;
- recording the infra-red absorption spectrum and studying the characteristics bands.
- gas chromatography of the entire sample.

In more difficult cases, application of separation methods for various compounds or series of compounds may be necessary:

- separation in series by thin-layer or liquid chromatography: saturated hydrocarbons, aromatic hydrocarbons, resins, asphaltenes;
- separation by liquid chromatography of polyaromatics;

- separation and identification by high resolution gas chromato- graphy of characteristic compounds: isoprenoids, mono/di/tri - aromatics, sulphuretted products;
- coupling gas chromatography and mass spectrometry.

Each method by itself is not sufficient if taken separately, however each one provides independent and complementary information which, when considered together, generally allow either to presume the identity of a pollutant sample and one or more reference samples or to prove the absence of it.

3. FATE AND BEHAVIOUR OF SPILLED OIL

3.1 Spreading

The most obvious characteristic of oil spilled on the sea surface is its tendency to spread horizontally under the combined forces of gravity, viscosity and surface tension. As a rule, gravity dominates initially, influenced by the viscosity of the oil. After a few hours, the oil thickness will be much reduced and surface tension succeeds gravity as the main spreading force. Typically, oil spilled on water will form a thin lens with the inner portion thicker than the edges. A few crude oils and heavy fuel oils are exceptionally viscous and tend not to spread much but remain in rounded patches. Most crude oils spread to a thickness of approximately 0.3mm within 12 hours. In the absence of other influences, spreading continues until the oil has virtually formed a monomolecular layer, no more than 0.5 micrometres thick. This is visible on the sea surface only as a faint silvery sheen. Once spreading has progressed to the formation of rainbow-coloured or silvery sheens, the natural dispersion of the oil is rapid, providing there is a minimum of agitation. **Table 4** gives surfaces reached by the spillage of several quantities of an average density crude oil. At the same time as oil is spreading and moving over the sea surface, a series of natural processes occurs causing physical and chemical changes of the oil, collectively known as weathering; this includes: evaporation, dissolution, oxidation, emulsification and microbial degradation.

Table 4. Spreading of an oil slick (with neither wind nor current)

	TIME OF SPREADING [hours]	QUANTITIES IN METRIC TONS				
		5t	50t	500t	5, 000t	50,000t
Oil slick surface [km^2]	1 2 5 10 24 48 72 96 500	0.006 0.016 0.065 0.183	0.016 0.023 0.065 0.183 0.518	0.076 0.107 0.169 0.24 0.68 1.93 3.54 5.45 64.8	0.360 0.496 0.784 1.11 1.72 2.43 3.54 5.45 64.8	1.14 2.28 3.64 5.15 7.98 11.3 13.8 15.6 64.8
Thickness [mm]	1 2 5 10 24 48 72 96 500	0.980 0.348 0.088 0.031	3.6 2.5 0.9 0.3 0.1	7.5 5.3 3.4 2.4 0.84 0.30 0.16 0.105 0.009	15.8 11.5 7.0 5.1 3.3 2.4 1.6 1.05 0.09	50.1 25.1 15.7 11.1 7.2 5.1 4.1 3.6 0.9

Crude oil: density 0,875 - viscosity 10 cSt

1 barrel crude oil = 42 US gallons = 35 Imperial gallons (approx.)
1 ton (ne) crude oil = 7.20 barrels = 252 Imperial gallons (approx.) or 302 US gallons

3.2 Evaporation

The process occurs within a few hours of a spill. The more volatile fractions of spilled oil are lost to the atmosphere at a rate determined by the type of oil, wind speed and ambient temperature. Rough seas increase the rate of evaporation since they encourage the loss of oil from the crests of waves as aerosols and sprays. High wind velocities and temperatures also increase evaporation rates. The residue remaining on the sea has a higher density and viscosity than the original oil. Most crude oil spills loose up to 40% of their volume in the first 48 hours, whereas heavy fuel oil containing few volatile compounds will show little evaporation even after several days. Light refined products such as gasoline, kerosene and diesel oil will evaporate almost completely in a matter of hours, creating a fire hazard in confined areas such as ports and harbours.

3.3 Dissolution

Losses from dissolution are relatively low since most petroleum hydrocarbons have a low solubility in sea water. The most soluble components of oil also tend to be the most volatile with the result that evaporation loss offsets dissolution. Unlike evaporation, this is a long-term process that continues throughout the duration of the weathering process. The presence of mineral salts contributes in reducing the limited available space for hydrocarbon molecules. In fact, the saltier the sea-water is (case for the Mediterranean), the weaker the dissolution will be.

3.4 Biodegradation

Biodegradation of oil by marine bacteria, fungi and yeasts, contribute significantly to the transformation of oil into oxidized products. The rate of degradation is dependent on temperature, nutrients and oxygen availability and the type of oil. Because bacteria are active at the oil/water interface, the rate of degradation is enhanced by thin sheens or by the formation of dispersed oil droplets with a large combined surface area. Lighter components are degraded faster than high molecular weight ones; the most favourable temperatures for the microbial growth are above 25°C. Below 5°C virtually any growth ceases. Solubility of oxygen in sea-water is low (6 to 8 mg per litre) compared to quantities required for complete oxidation of hydrocarbons: 3-4 mg O_2 per mg of hydrocarbon for conversion into CO_2 and H_2O. Finally, bio-conversion of one mg of hydrocarbon requires approximately 0.1 mg of nitrogen and 0.015 mg of phosphorus, whilst quantities existing in the Mediterranean waters are relatively low, less than 500 mg/m^3 and less than 70 mg/m^3 respectively. It is estimated that under optimum conditions in the Mediterranean region, bacteria can oxidize up to 1 gram of oil per square metre per day.

3.5 Emulsification

- **Oil-in-water:**

If the water surface is turbulent, the oil may separate into droplets that are subsequently suspended in the water. The slick is then unaffected by the wind and may re-form some distance from the initial spill.

- **Water-in-oil ("chocolate mousse"):**

This type of emulsion, also called reverse emulsion, may be formed within a few hours, containing up to 90% water. As a result, the density and viscosity increases, as well as the volumes to be treated or recovered. The tendency for mousse generation is greatest for oils of low viscosity under the action of moderate waves; highly persistent "tar balls" can be formed which are solid rather than fluid. Many of the Mediterranean countries have experienced problems with tar ball deposition on beaches but much of this problem can be attributed to illegal discharges of dirty ballast or machinery space residues. As an example, due to formation of an emulsion that included 75% of water, viscosity of AMOCO CADIZ crude was multiplied by 200.

3.6 Photo-oxidation

The chemical reaction of hydrocarbons with oxygen is called oxidation. This reaction occurs at the surface and will occur more rapidly when the oil is spread into a thin film. Ultra-violet radiation from sunlight also accelerates oxidation and under ideal conditions can result in weathering of one per cent of the spilled oil per day.

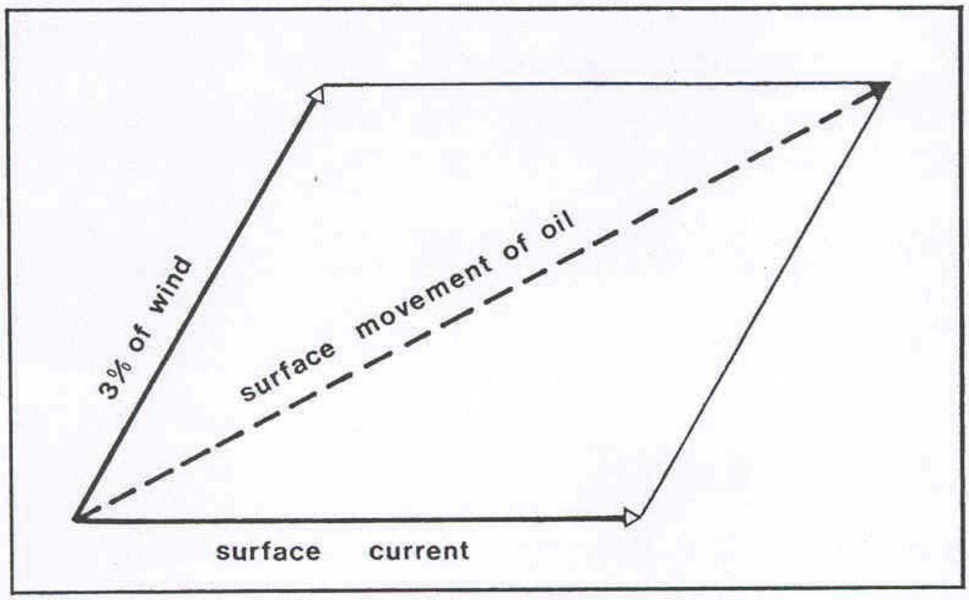
Due to the rapid reduction of light diffusion in thick oil layers, the photo-oxidation affects primarily thin layers or surface parts of thick oil layers. The effects of this can either be favourable or disadvantageous for the further development of a pollution. Oxidized light oils are generally more soluble and more dispersible in the sea-water and consequently biodegradable. In heavy oils or those that have lost their light components, photo-oxidation favours polymerization reactions that hamper dealing with these oils and their final degradation.

3.7 Sinking and sedimentation

Evaporation, emulsification and the resulting increase in density may help certain, initially heavy, oils to sink. Several oil spills such as the AMOCO CADIZ, IXTOC 1, NOWRUZ, HAVEN and ERIKA have featured oil sinking either to a mid-water position or to the sea-bed. Very often the cause of sinking is the incorporation into the weathered oil of the sediment. Sinking is also possible when a marked decrease in the density of surface waters is encountered, for instance in front of estuaries.

3.8 Movement

The mechanism whereby surface movement is induced by wind stress is imperfectly known but it has been found empirically that floating oil will move roughly downwind at a rate of about 3% of the wind speed. In the presence of surface currents, an additional movement of the oil proportional to the current strength, will be superimposed on any wind-driven motion. Close to land, the strength and direction of any tidal currents must be considered when predicting oil movement, whereas further out at sea, this contribution is less significant due to the cyclic nature of tidal movement.



4. CONSEQUENCES OF A POLLUITION

4.1 Consequences of a physical nature

A film of oil spread on the water surface prevents air/sea exchanges necessary for marine biological cycles. Therefore:

- it diminishes the renewal of oxygen;
- it gets in the way of sunbeams, thus curbing the chlorophyllic synthesis;
- it entails a rise in temperature and favours the proliferation of oxygen consuming micro-organisms.

4.2 Consequences of a biological nature

The effects of oil on the environment are varied and complex. Some appear immediately, others over a longer period. These affect to different degrees both the animal and vegetable kingdom on and in the sea. **Table 5** summarises these effects on certain characteristic marine populations. In the case of crude oils, the most volatile fractions and the aromatic compounds are the most toxic. For refined products the most harmful effects generally result from products with a low boiling point; the petrol containing tetraethyl lead is considered as the most toxic, followed by kerosene, gas-oil and Fuel No.6 (or Bunker C).

Table 5 Effects of oil on certain populations

POPULATION	SENSITIVITY	SHORT-TERM EFFECTS	LONG-TERM EFFECTS* RESTORATION
Algae	Low	Coating and burning of tissues, if in direct contact with product.	Generally good restoration.
Salt marshes or Estauries flora	Variable, depending on the state of development of plants and period of the year.	Coating of exposed parts causes suffocation. Impact due to crossing by anti-pollution equipment and personnel over marshes.	Restoration relatively fast (2 to 3 years) if water is renewed and nutrients supplied. Restoration very slow if nothing is done to facilitate it.
Molluscs in inter-tidal zones	Generally high	Suffocating and poisoning.	Accumulation by filtering organisms. Even a low percentage of residual hydrocarbons in sediments renders the use of commercial species unsuitable for consumption. Possibility of purification in clean water depends on contact time with pollutant. Decrease of reproduction.
Fauna fixed on rocks	Generally high	Suffocating and poisoning.	Depends on duration of contact with pollutant. In exposed areas, sensitivity less pronounced due to very rapid renewal of water and cleaning.
Fish	Low for adults. High for larvae and juvenile forms.	Through direct contact with hydrocarbons: suffocation caused by coating and tension-active effects on gills. Organisms rapidly leave polluted zones.	Wounds on fish digging in even slightly polluted sediments (e.g. flatfish).
Birds	Variable (high for diving species).	Coating of plumage, poisoning by ingestion, destruction of nests and eggs by contact.	Evacuation of polluted zones.

* In case of persistent permanent pollution.

Table 6 Degree of vulnerability to oil spill damages of various types of coast (in ascending order)

VULNERABILITY INDEX	TYPE OF COAST	COMMENTS
1	Exposed rocky headlands	The waves keep out most of the oil - cleaning is unnecessary.
2	Wave-cut platforms	The waves sweep the oil away and most of it is removed naturally within a few weeks.
3	Fine-grained sand beaches	The oil does not penetrate the sediment and this facilitates any mechanical removal. If not removed, the oil may persist for many months.
4	Exposed compact tidal flats	Little oil adheres to or penetrates into exposed compact tidal flats. Clean-up is not always necessary.
5	Coarse-grained sand beaches	The oil soaks in rapidly and thus makes clean-up difficult. The tidal action in the Mediterranean is insufficient for rapid natural clean-up.
6	Mixed sand and gravel Beaches	The oil penetrates rapidly. In zones of light surf, the oil may persist for several years.
7	Pebble/cobble beaches	As above. Clean-up should be intensified at high tide. If there is a great deal of oil it may form asphalt.
8	Sheltered rocky coasts	In light surf areas, the oil may persist for several years. Leaning depends on local conditions.
9	Sheltered tidal flats and estuaries	Areas of high biological activity and little surf. The oil may persist for a number of years. Clean-up is recommended. These areas should be given priority protection with booms or sorbents.
10	Marshy areas with vegetation – mangroves	These are the most productive aquatic environments. The oil may persist for a number of years. Cleaning (of marshes) by cutting down or burning vegetation should be done only when there are very large quantities of oil. These areas should be given priority protection with booms or sorbents.

Table 7 Classification of soil according to the diameter of the constituting elements

DESCRIPTION		*DIAMETRE [mm]* DIAMETER [mm]	DESCRIPTION	
bloc de pierre, rocher		>250	boulder	
galet		50 – 250	cobble	
caillou		5 – 50	pebble	
gravier		2 - 5	gravel - granule	
Sable	*très grossier*	1 – 2	Very coarse	sand
	grossier	0.5 – 1	Coarse	
	moyen	0.25 - 0.5	Medium	
	fin	0.125 - 0.25	fine	
	très fin	0.050 - 0.125	Very fine	
limon		0.005 - 0.050	silt	
terre glaise – argile		0.0002 – 0.005	clay	
colloïde		<0.0002	colloid	

4.3 Consequences of human health

Besides direct intoxication through inhaling or massive ingestion of petroleum products, the consumption of certain marine animals (fish, crustaceans, shellfish) which have been in contact with oil can be dangerous for Man through cumulative effects.

However, most of the time, the harmful effects of pollution are felt indirectly through the economic and ecological impact:

- Damage to biological resources: marine flora and fauna, consequently hindering certain maritime activities;
- Defacement of amenities and a blow to tourism which, in nearly all the Mediterranean coastal States, has a fundamental economic value;
- Lowering of the quality of sea water affecting its multiple usages.

4.4 Toxicity of oil products in enclosed spaces

During pollution combating operations at sea and in the **open air**, few are the toxic effects of crude oil to dread:

- Very low toxicity;
- Unattainable upper limit of tolerance.

However, in case of intervention on board tankers, for example during lightering operations, the risks involved can increase, especially if the crude oil, a mixture of hydrocarbons, contains other substances, particularly hydrogen sulphide H_2S (see paragraph 4.5).

In a **closed space** the human organism can be effected by hydrocarbons in three ways:

a) By inhaling gas

Table 8 Possible effects of inhaling hydrocarbons vapours contained in the inhaled air

CONCENTRATION			DURATION	REMARKS
% GAS	ppm	LEL*		
0.016 to 0.027	160 to 270	2% 3%	8 hours	Very slight irritation of eyes and throat
0.05	500	5%	1 hour	No significant effect
0.09	900	10%	1 hour	Slight irritation of eyes, throat and nose. Light sensation of weariness
0.2	2,000	20%	1 hour	Symptoms of anesthesia after 30 minutes
1.0	10,000	100%	10 mins.	Throat and nose irritation after 2 minutes. Lassitude after 4 minutes. Symptoms of inebriation after 4 to 10 mins. **DANGER** – coma

* "Lower Explosive Limit" (measured on the explosimeter): 100 LEL = 1% of gas.

The smell of hydrocarbons' vapours can vary significantly. In certain cases hydrocarbons can disturb the sense of smell. Accordingly, the absence of smell should never be considered as absence of gas. The effects are reversible if the subject is treated in time.

In principle there are no long term effects caused by hydrocarbons themselves, except by benzene. On the other hand, long term effects can result from conditions generally associated with the presence of hydrocarbon gas: lack of oxygen, presence of hydrogen sulphide.

b) By skin contact with liquid

Short term effects: Hydrocarbons dry the skin and can provoke dermatosis. They can provoke eczema through the blocking of pores.

Long term effects: Heavy hydrocarbons, particularly aromatic hydrocarbons, can provoke skin cancer as a result of prolonged contact with the skin. These products attack rubber, particularly neoprene, which as a result do not ensure sufficient protection.

c) By accidental ingestion

Medical intervention is needed in this case. Never make the injured person vomit to avoid the risk of increased penetration in the lungs and bronchi.

4.5 Toxicity of hydrogen sulphide (H_2S)

Most types of crude oil contain hydrogen sulphide, in fact more than 3% in some types of Middle East crudes. It is definitely dangerous to inhale gas emitted by sulphurous crude. Hydrogen sulphide is a colourless gas, smelling of rotten eggs. However, the smell is not sufficient evidence to test its presence. In fact, strong concentrations paralyse the sense of smell.

The inhaling of hydrogen sulphide vapours may cause brain and kidney damage.

Table 9 Possible effects of inhaling H_2S vapours contained in the inhaled air

CONCENTRATION		DURATION	REMARKS
% GAS	ppm		
0.005 to 0.01	50 to 100	1 hour	Irritation of eyes, nose throat and bronchi. Prolonged inhaling of concentration to the order of 100 ppm can lead to death within 4 to 48 hours.
0.02 to 0.03	200 to 300	1 hours	Outright irritation of eyes, nose, throat and bronchi. Longer exposure cannot be tolerated.
0.05 to 0.07	500 to 700	1/2 – 1 hour	Coma with possible death
0.07 to 0.09	700 to 900	Few minutes to 1/2hours	Coma with death occurring rapidly
0.1 to 0.2	1000 to 2000	Few minutes	Immediate death

Long-term effects: Repeated exposure to low hydrogen sulphide concentrations can cause irritation of the eyes and coughing. However, hydrogen sulphide does not cumulate in the human body and, as a rule, there are no long-term effects.

First aid measures:

- Carry the casualty to fresh air;
- Give artificial respiration, if necessary;
- Treat for unconsciousness;

- Amyl nitrite.

If the casualty resists to inhaling hydrogen sulphide, recovery is generally complete with no after effects.

In case work in a tank needs to be done over a long period, ventilation is required to ensure a percentage measure of gas (LEL) 1% and a measure of H_2S content (DRAEGER) less than 50 ppm.

4.6 Risks resulting from inert gas/low oxygen content

The main risk caused by inert gas is the lack of oxygen. Besides, combustion gas can also contain toxic compounds, particularly carbon monoxide (CO).

Once the tank is sufficiently ventilated and a correct oxygen level (21%) is obtained, the toxic elements are reduced to acceptable traces.

It is always a hard and fast rule to measure the oxygen before entering a closed area, cargo tank or not (cofferdam, double bottom) and to enter only if the reading is over 20.6%. The measuring apparatus should always be checked before and after the reading is taken

Chapter 2

INTRODUCTION TO OIL SPILLS

1. INTRODUCTION

Contingency plans are indispensable tools for promptly and effectively responding to oil spills, however in each specific marine pollution incident numerous questions must be answered "on site" and many unforeseeable factors need to be borne in mind when taking operational decisions, if response activities are to be complete in an efficient and orderly manner and if optimum results are to be achieved.

Whatever the first emotional reaction to an incident is, it must be followed by a sequence of carefully planned and deliberate actions. These will be based on legal, administrative and organizational provisions of a national (local, district) system for preparedness and response to marine pollution accidents. In the process of setting up such a system, outlining the general **policy** that the authorities should follow in case of an oil spill and, more specifically, the **strategy** of dealing with oil spilled in a certain area, is the basic requirement for efficiently responding to marine pollution emergencies.

Each geographical or administrative area, potentially exposed to the risk of accidental marine pollution, offers a number of elements which should be considered in advance and which are not likely to change drastically in case of a pollution accident, and these could therefore be used for planning the response. If a certain **strategy**, based on these fixed parameters, has been selected in advance for an area, it will be much easier to modify **tactics** for dealing with each particular spill in accordance with the circumstances prevailing at the time of the incident.

2. OIL SPILL RESPONSE STRATEGY

Regardless of the scale of the problem, response to a marine pollution emergency can be expected to be successful only if response **organization** exists, if (trained) **personnel** and necessary **equipment** are available and if the **strategy** of response has been agreed upon. Combined with careful advance **planning** of response activities, the presence of these key elements significantly increases the chances that response efforts will succeed.

The successful outcome of a spill response operation will largely depend on the appropriate selection of spill **response strategy**.

Spill response strategy adopted for a certain area will be indeed an agreed selection of available spill response techniques, with assigned **priorities** for their implementation, based on certain key criteria (characteristics of the area, availability of resources), as well as on some other factors (social, political) specific for each region, country or its part.

Available oil spill response methods and techniques include:

1. Elimination of the source of oil (or other pollutant)
2. Spill containment and protection of sensitive resources
3. Removal of spilled oil from the sea surface by:

    3.1. mechanical recovery of spilled oil
    3.2. use of dispersants
    3.3. use of other treatment products

4. Removal of stranded oil (shoreline clean-up)
5. Transport, storage and treatment of collected oil/oiled material
6. Final disposal of collected oil/oiled material
7. Restoration of spill site

Alternatively, **"leave alone action"** may sometimes also be considered as an acceptable method of dealing with accidental oil spills. Certain spilled products (such as petrol, diesel, gas oil and other light, non-persistent products) do not necessitate a major scale response operation. On one hand the intervention on such products may be dangerous for the response team, and on the other, it may be completely useless, bearing in mind that these products dissipate rapidly due to the evaporation and/or dissolution. It is also a viable solution for dealing with oil in particularly sensitive areas where any intervention could cause more damage than the oil itself.

Although the number of methods and techniques used in oil spill response is limited, the problem of deciding which one to apply, and particularly which one to apply first in a certain spill situation, often delays the reaction. Even worse, the wrong choice may lead to the failure of the complete response operation.

Certain countries base their response strategy on mechanical removal of spilled oil, some others on Its chemical dispersion, whilst some on a combination of both methods. On the other hand, some countries will endeavour to combat spill as much as possible at (open) sea, others will concentrate on combating it on shore. In most cases, different approaches will be anticipated for different parts of the coast. The selection of the response strategy is very often dictated by the availability of specialized equipment or logistic support required for the application of a certain response technique, and entirely depends on conditions specific for the country or part of it.

Operational **tactics** for a specific incident and site will be determined only after considering various data concerning the actual spill site, type of the product spilled, meteorological and oceanographic conditions at the time of incident, availability of specialized personnel and equipment, etc. The contingency plan should aim at providing a reliable frame within which tactical decisions could be taken.

The choice of response options is also very restricted and there are basically three groups of actions that could be considered:

i) to treat the major part of spilled oil at open sea, in order to limit the quantity which will need to be dealt with on shore;

ii) to attempt to stop, or rather to limit, the spreading of spilled oil by "attacking" its leading edges (and in particular its downwind edge), thus protecting the coastline likely to be affected;

iii) to protect the coast with all available means and prepare for the shore clean-up operation.

These three basic approaches do not exclude each other, and in fact a combination of two or all three of these is often applied.

The **time factor** is crucial in deciding which one to chose, since the first one is effective mainly in the initial phases of the accident, while after a certain period the third one becomes the only choice.

3 SELECTING THE APPROPRIATE RESPONSE STRATEGY

Strategy defined for a certain area should be mainly based upon:

- the characteristics of the area (geographic and oceanographic features, biological and economic resources, etc...);
- availability of response equipment, trained personnel and logistic support.

Certain intrinsic characteristics of spilled oil should also be taken into consideration when selecting the most adequate way of spill response, and these include the following:

- The oil that is not contained or removed while afloat will continue to move. If accident occurred close to the shore, oil is likely to reach the coastline. It will be mixed with the beach material (sand, debris), coated onto rocks, vegetation and wildlife, deposited on the bottom.
- The volume of the material to be collected and/or treated may increase dramatically by the creation of water-in-oil emulsions containing as much as 3 - 4 parts of water per unit of oil.
- As the delay between the spillage of oil and the start of its removal increases, the following phenomena are likely to take place:

  a) More oil is **lost** to the environment.

  b) The **oil spreads** over the wider area becoming more difficult and expensive to collect and deal with.

  c) The **amount** of emulsified water, sand, vegetation and other natural or man-made debris which needs to be collected per unit of oil **increases**.

  d) The **length** of the affected coastline **increases**.

  e) The **possibilities to reclaim** collected oil **decrease**.

Defining the most adequate strategy for a certain area should not be left for the moment when the incident occurs. The appropriate **response strategy** should be prepared and agreed upon at the time when there are no emergencies and, once defined, entered into the relevant **contingency plan**.

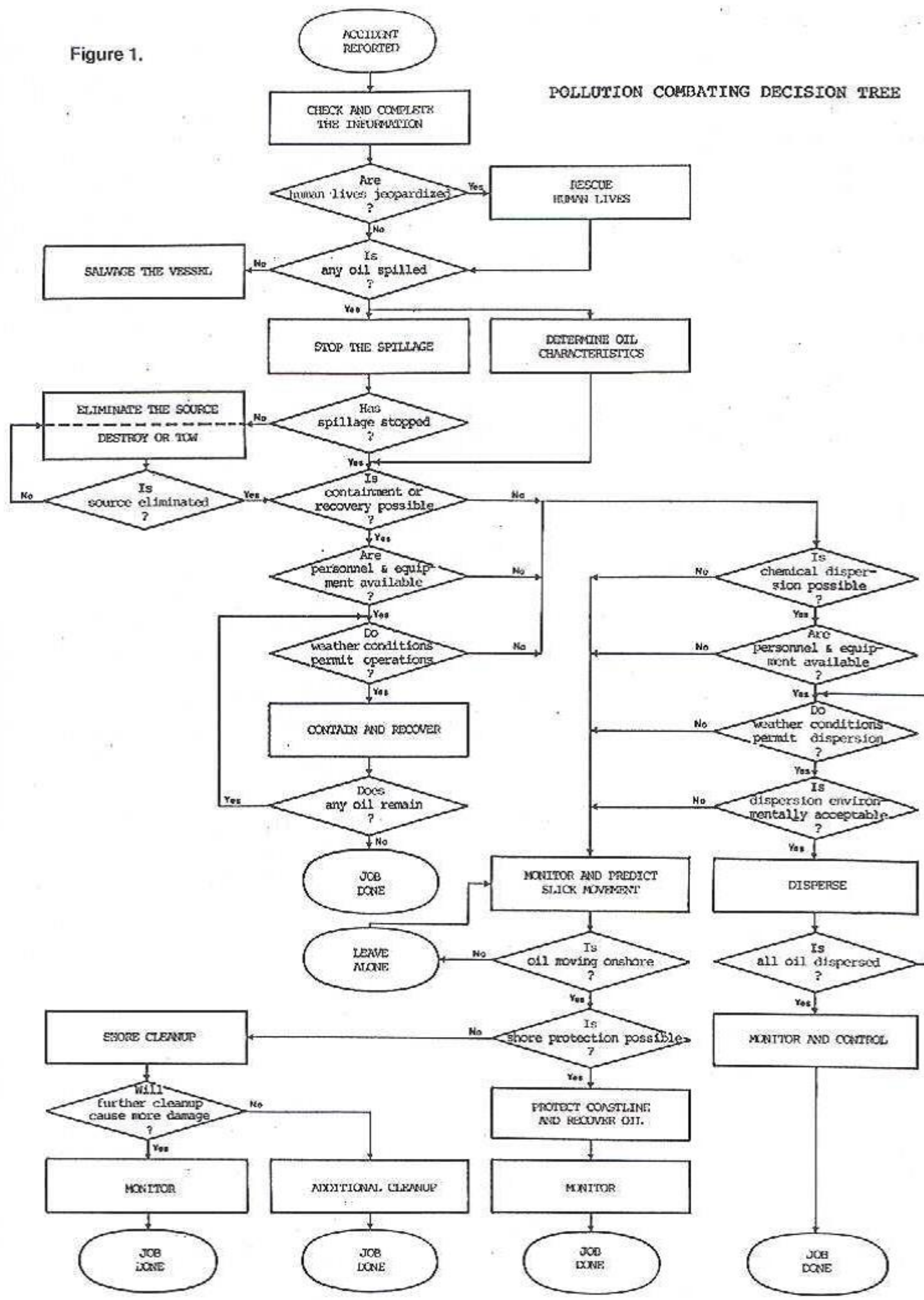
Finally, it has to be borne in mind that a spill response operation has a chance to be brought to a more or less successful end only if it starts when:

- Expert **personnel** and necessary **equipment** are available **at the spill site**.
- All involved are aware of the **priority of actions to be taken**.
- The **safety of the response team**, which SHOULD AT ALL TIMES SUPERSEDE ALL OTHER CONSIDERATIONS, is ascertained.

All those who are expected to take part in spill response operations have to be aware of the strategy that will be used and details of its implementation have to be explained to them. An easy-to-consult way of presenting the agreed strategy is by using decision trees.

A sample of such a decision-tree, a very general one and not meant for any specific area, is presented in Figure 1.

Figure 1.



Chapter 3

CONTINGENCY PLANNING

1. INTRODUCTION

It has been proven to be impossible to work out a "model" contingency plan, however, certain elements common to all such documents can be defined. The preparation of, in particular national, contingency plan always includes the risk of producing a too massive document, the use of which will be impractical. In such bulky documents, it is usually impossible to find on time the information or instruction needed, and their updating is a very difficult task.

The goal when preparing a contingency plan should be the preparation of a concise document that will contain brief definitions, descriptions and instructions, outlining national policy concerning accidental marine pollution preparedness and response, and clearly reflecting provisions of the legal document giving statutory framework for setting up the national system for preparedness and response. This applies in particular to national contingency plans, but also to plans at any other level.

It is useful to divide each contingency plan into two parts.

I. The first part, which will clearly define **who** (responsibilities) will do **what** (policy, strategy) and **where** (coverage, scope), has to be general enough to provide a flexible framework for the second part.

II. The second part, which should be permanently updated, modified and changed in accordance with changing of the situation, knowledge or new developments, has to define **how** the job (oil spill response) will be done. The second, operational part of the Plan should comprise a number of annexes, subject to more or less frequent changes. However, a good contingency plan should not contain complicated scientific or technical information.

In order to make all necessary information concerning each particular locality along the shore readily available to the responders, **local contingency plans** for each site considered important (coastal town, beach, port, refinery, terminal, etc.), with a special emphasis on the localities at risk, should be prepared at the local level (**Tier 1**). Depending on conditions, this task (including the deadline) should be given either to the local public authorities or to the local industries, which need to be identified in the early stages of preparation of the national marine pollution preparedness and response system. Local (Tier 1) plans should be based on the limits of responsibility of local public authorities or industries as assigned to them by the relevant legal act and by national and district contingency plans respectively. Modalities of transfer of responsibility to a higher level should also be clearly defined in local, district and national plans, as well as the obligation of such local public authorities or industries to report all accidents to the higher (district) authorities. Local plans should contain detailed descriptions of sites, locally available personnel, equipment and products, detailed instructions for application of selected response techniques, instructions concerning storage, transportation and disposal of collected polluted material, etc. All this information can be attached to each local plan in the form of annexes.

The link between detailed local plans and the national plan will be a limited number of **district** (or divisional) **contingency plans** (**Tier 2**). These will be in fact the most important elements of the complete preparedness system especially from the operational point of view. In accordance with the defined division of the country in districts (sectors), divisional plans will provide the basis for responding to any medium, or major size pollution threatening the country. These plans will be based on pooling the resources listed in local plans and detailed information on each locality in the district, as well as on additional resources available on district / national levels for responding to major oil spills and spills occurring in areas not covered by local plans. Tier 2 plans must define the framework for conducting response operations in case of any spill exceeding the capabilities of local (Tier 1) spill responders and in particular they must define the responsibility for co-ordination of all response efforts in case of bigger spills. It is necessary to understand that district plans are not only the sum of local plans, but they provide for a concerted spill response by various means and resources in all cases when the emergency cannot be dealt with at the local level.

National contingency plan (**Tier 3**) will define the overall policy of response to accidental marine pollution. It should comprise various district contingency plans and provide for support to district authorities when the proportions of the pollution accident call for involvement of all resources available in the country or even for international assistance.

2. CONTENTS OF A CONTINGENCY PLAN

The non-exhaustive checklist which follows, aims at giving additional information on the main subjects which should be covered by a national contingency plan, however the same or very similar issues should be addressed in district and local plans.

The **INTRODUCTION** to a contingency plan has to necessarily make reference to statutory obligations of each authority, administration or any other entity mentioned later on in the document. All legal documents on which the plan is based should be listed in its introductory part. In addition, the introductory part of the document has to define the purpose, the objective and the scope of each contingency plan.

> Purpose of a national contingency plan is to organize the protection of the interests of the nation, its people and its environment. Particular attention should be paid to protecting economic interests, since a response to a major pollution accident may be a highly expensive operation. The same applies to district and local plans within their respective areas of coverage.
>
> Objective of each contingency plan is to ensure a timely, adequate and effective response to spillages or threat of spillages of oil (or other hazardous substances), with a view to minimizing damage to the environment and the impact on the economic and social welfare of the people residing in the coastal area and in case of the national plan of the country as a whole.
>
> Geographical coverage or scope of the NCP should include the entire length of the coast of the country and its territorial waters. In some specific cases, it may also cover the adjacent waters if it is envisaged that an accident occurring outside the territorial waters may pose a threat to important coastal resources. However, in such cases, a reference to relevant international regulations (e.g. International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, 1969 and its related Protocol, 1973) should be made and their provisions taken into account. The scope of each local or district plan has to be defined in accordance with provisions of the legal act requiring their preparation.

RISK ANALYSIS - within the context of planning pollution response capabilities and optimizing their location in selected areas of high risk for the purpose of local or district contingency plans, will depend on the risk assessment which has to be made in early stages of setting up the national system for preparedness and response.

Risk assessment has to include identification of areas of high incident risk (tanker routes and terminals, coastal installations, possible sources of accidental marine pollution, offshore installations, pipelines, etc.), to estimate sizes of possible releases and to take into account the sensitivity of the country's coasts and the possibility that pollution reaches particularly sensitive areas.

At this stage it is necessary to understand that it is impracticable for any country to be fully prepared to respond to a massive spill anywhere in its waters or on its shores. Accordingly, the approximate maximum spill size for which the country needs realistically to be prepared has to be determined on the basis of the analysis of locations of oil terminals, ports and other related installations, quantities of oil (or other hazardous substances) handled in each of these, numbers of tankers and frequency of their calls in terminals, average size of vessels, density of non-tanker traffic in national and adjacent waters, historical data on recorded oil spills, in addition to the analysis of oceanographic and meteorological data for national coastal waters, shores and the whole area in general.

Planning for extreme cases (e.g. spills of more than 5000-10000 tonnes) is not likely to produce the expected result (i.e. satisfactory level of preparedness) and is often counter-productive. Planning for a smaller but more realistic spill size and leaving sufficient flexibility within planned organization and procedures will make the NCP adaptable enough to provide a response framework for spills both larger and smaller than the one for which it has originally been formulated.

Local or district plans, which will be the operational component of the national contingency plan, should be prepared bearing in mind the maximum realistically expected spill size which might occur in each locality and the national plan should be based on the highest of these figures and not on their sum.

It is widely accepted that in case of a massive pollution accident, each country has to be prepared for at least initial response by its own means in the first hours after the accident. Additional resources (human and material) can be obtained from outside the country through international mechanisms for co-operation and mutual assistance (e.g. Emergency Protocol to the Barcelona Convention) which have been set up precisely in order to provide assistance to the countries in cases when the pollution size exceeds their own response capacities. Modalities for requesting international assistance should be addressed in the part of the plan dealing with the organization and responsibilities.

SHORELINE CLASSIFICATION - each pollution accident, especially a major one will threaten different coastal resources. These may have ecological, economic, recreational or purely aesthetic value. A good knowledge of all resources at risk is essential for establishing priorities for protection and/or clean-up, as well as to make a selection of the most adequate response methods for each particular location.

The NCP should only define criteria concerning degrees of vulnerability and/or different levels of priority for protection that will be applied in preparation of district and local plans. Details on each of these zones will be given in the operational part of each local plan, and these should be summarized and attached to district plans.

The recommended method of presentation of types of shoreline, coastal resources, priorities for protection, etc., is mapping. Maps or charts presenting schematically various features of a certain coast vary in scale: a NCP should normally comprise rather general maps indicating the most important characteristics of the coastline and resources at risk, whilst local and district plans will contain more detailed maps. These will include precise information on types of coastal formations, biological data (species, seasonal variations, etc.), information on various human activities in that particular section of the coast, and possibly information necessary for conducting and planning spill response operations (water depths, load bearing capacities of beaches, access routes, etc.). Boundaries of the zones where the use of dispersants is either forbidden, restricted or allowed should also be presented in such maps.

The following information should be included in each contingency plan:

<u>Type of shoreline</u> - precisely plotted on a map, giving the type of coastal formation (e.g. pebble beaches, gravel beaches, sand (coarse or fine) beaches, rocks, tidal flats, etc.)

<u>Natural resources</u> - map has to include information on the main species inhabiting the area (fish, shellfish, crustaceans, birds, mammals, etc.) indicating particularly important or sensitive habitats (marshlands, coral reefs, fish spawning areas, sea-birds sanctuaries, etc.).

<u>Human activities</u> - locations of industrial installations, refineries, power plants, harbours, oil terminals, yacht marinas, fishing zones, shellfish breeding areas, recreational beaches, tourist complexes, etc.

<u>Priorities for protection</u> - locations which will be given the priority for protection and clean-up. List of priorities for protection will be based on environmental (ecological), economic and aesthetic factors.

<u>Less important areas</u> - locations which are considered as less vulnerable and less important and hence can be regarded as sacrificial areas, may also be included in the Plan. The criteria for preparation of such a list will be the same as for the list of priorities.

It is recommended that all this information be attached to the respective contingency plans as annexes, preferably in the form of **sensitivity maps**.

BEHAVIOUR AND FATE OF SPILLED OIL - each contingency plan will necessarily make reference to the prediction of movement and fate of oils (pollutants) likely to be spilled. The methods used for making these predictions can range from complicated and sophisticated computer models to rudimentary information on most likely behaviour patterns.

Three groups of data should be collected, systematized and annexed to the operational part of each local plan in order to facilitate assessment of slick behaviour, movement and impact:

<u>Meteorological data</u> including seasonal (monthly) variations of wind speeds and directions in the area of the coverage of the plan and average air and sea temperatures for different periods of the year.

<u>Oceanographic data</u> necessary for the assessment of spill movement and behaviour, including information on currents' velocities and directions and on tidal movements. Water depths provide useful guidelines for planning inshore operations.

<u>Characteristics of oils</u> likely to be spilled (including at least relative density, viscosity at ambient or sea temperature, pour point, distillation characteristics) are essential for predicting both the fate of the slick and the selection of proper combating techniques.

District plans should incorporate the same data from local contingency plans for various localities in each district, while the national plan might include those information (or their summary) from district plans which are deemed useful for co-ordinating and supporting response activities from the central level, if the need for it arises.

ORGANIZATION – each contingency plan has to clearly define the organizational framework for activities related to preparedness and for smooth and effective spill response.

In each country it is necessary to make certain divisions of its area in order to make spill response more practical. Throughout the present document the word "district" has been used for proposed divisions inside the country, however it should be replaced, if necessary, with a more appropriate word reflecting the actual terminology already used in the country's administration. It is understood that planning national response structure and organization in 3 (three) tiers appears adequate for the majority of countries. The tiered preparedness and response organization will include:

a) **Local level** is the lowest level of organizational structure, responsible for dealing with small incidents of only a limited importance (small spills). Local pollution response structures will be formed from existing personnel in each municipality, port, terminal, oil refinery, power plant or industrial complex located on shore and will be charged with the preparation of contingency plans for their respective installations, covering small pollutions which can be expected to happen there occasionally.

   The responsibility for preparation of local plans will be given, depending on the circumstances, either to local representatives of <u>public authorities</u> (mayors, port authorities) or to the <u>industry</u> (managers of oil terminals, refineries, offshore oil fields) in the areas in which they operate.

   The NCP has to define in detail the **limits of responsibility** for clean-up operations of such local bodies, including also the definition of the accident or spill size beyond which the responsibility for conducting clean-up operations will automatically be shifted to a higher (district) authority. It is important to emphasize that even in case of bigger accidents, falling under the overall responsibility of higher authorities, the response operations will nevertheless be initialized and conducted by local pollution response authorities. Accordingly, regardless of the actual spill size and the scale of operations, local authorities will have to provide basic human and material resources for response.

   All response activities related to small spills have to be covered by **local contingency plans** (**Tier 1 plans**) and will be undertaken without delay directly by local pollution response officials and personnel at their disposal. However, all accidents, regardless of their size, should be **immediately reported** to the higher (pollution response) authorities.

b) **District level** will be the second level of the national system for preparedness and response, in charge of a certain sector of national shores and territorial waters and covering several local response bodies. District authorities will be in particular responsible for pollution clean-up operations in their respective sectors. District level should be actually considered as a key element in the national system for preparedness and response and in fact this is the level (**Tier 2**) at which significant spills will be dealt with. Responsibility for conducting and co-ordinating clean-up operations in cases when the incident size exceeds local (**Tier 1**) capacities, will be automatically taken by respective district pollution response authorities in accordance with instructions, which need to be clearly formulated in the plan.

c) **National level** is the highest, central level (**Tier 3**) with overall responsibility for preparedness and response activities in the country and in particular for co-ordinating support to district authorities in case of massive spill affecting large parts of the national waters and coasts and exceeding the capabilities of each individual district authority. National spill response authority should also have the responsibility for matters related to international co-operation and possible assistance in the event that the size of spill threatening national interests exceeds combined national response capacities, as well as in cases when such assistance is requested from national authorities by another (neighbouring) country.

In addition to describing the organization itself and responsibilities in particular, this part of the NCP will also include a number of Annexes (which will need to be permanently updated) listing: all persons nominated to execute specific duties (with names, addresses, telephone, telex and telefax numbers), functions of various parts of the response system, sources of manpower, equipment and products including governmental, public and private sectors as well as contact points outside the country (e.g. REMPEC, IMO, IOPC Fund, etc.). The Regional Information System developed by REMPEC should be incorporated in the NCP.

Other topics, related to the organization of preparedness and response, which also need to be covered and defined in each contingency plan, regardless of its level, include:

Activation of the NCP - alerting procedure, including the standard reporting format (e.g. POLREP), as well as the responsibility for activating the Plan.

Communications - between different authorities, teams and persons have a major influence on the outcome of response operations. Plan has to list required and available communication means (telephone, fax, telex, radio, e-mail), their numbers (headquarters, divisional headquarters, main offices) or allocated radio channels.

Documentation of activities - modalities of and responsibility for record keeping, in order to facilitate preparation of indemnity claims and recovery of expenses. It includes recording all expenses related to the use of manpower, equipment and products, book-keeping, collection of receipts, bills, invoices, etc., photo and video documentation.

Public relations - responsibilities for dissemination of information and channels for communicating these to media. Oil spills, particularly massive ones, and pollution accidents in general, normally attract a great deal of public interest. Since mass media can strongly influence public opinion and, if not informed regularly and correctly, cause a major problem for personnel organizing and commanding spill response operations, public relations should be given a prominent place in each CP.

Liaison - with various governmental offices (e.g. customs, immigration) and other parties (e.g. scientific community, shipping industry, insurers, etc.) not directly involved in spill response operations but still having an influence or an interest in the situation and its development.

Customs and immigration arrangements - If possible, necessary arrangements for immediate customs clearance of all pollution response materials which might arrive from abroad within the framework of international assistance, and arrangements for immediate clearing of immigration formalities for foreign experts or response personnel who might be called to assist the country, should be made during the contingency planning process and these provisions should be also included in the NCP.

A set of "Principles and Guidelines" adopted by the Contracting Parties to the Emergency Protocol of the Barcelona Convention (as reproduced in Part A of the Regional Information System) should serve as the basis for formulating such arrangements.

OIL SPILL RESPONSE - each CP is expected to give guidelines for conducting oil spill response operations. It has primarily to define the **strategy** of oil combating and then various anticipated spill control and response techniques, as well as transportation, storage and disposal methods for collected pollutant. It should also include lists of available equipment and products, transportation means and other logistic backup, disposal sites, etc. Since all technical data are subject to changes and updating, these should be annexed to the operational parts of local plans and subsequently attached to district plans. It is not necessary to include all technical details of equipment and products in the national plan, however the summary list of various categories of available means should be attached to it. Under this "headline" a contingency plan must cover are the following the main topics:

Strategy of pollution response - based on the overall policy adopted at the national level taking into consideration the conditions specific for the country and defining the most adequate response techniques and the sequence of various envisaged operations.

NCP will only outline the adopted overall policy, while operational procedures will be defined in local and district plans for their respective areas, taking into consideration environmental data, types of shoreline, availability of various types of equipment and logistic support for its use, limitations of particular techniques, etc. Detailed guidelines for assessment of the situation in case of emergency and decision taking should also be given in the operational part of each local and district plan.

Pollution response techniques - a contingency plan cannot be a manual of pollution response techniques, however, it might be necessary to include some notions specific for each technique anticipated for use in response operations. It has to make reference to geographical limits for use of chemical dispersants, boom deployment sites, load bearing capacities of beaches on which mechanical removal of oil is envisaged, etc., which will then be described in detail in local plans. In general, each plan should refer to limitations of various techniques rather than to their advantages.

Particular attention needs to be paid to the use of dispersants for combating oil spills at sea. On the basis of the adopted national policy (if the use of dispersants is envisaged as a possible pollution response method), detailed guidelines for their use should be prepared and attached to each local and district contingency plan. It is recommended to follow the policy based on the principle of prior authorization for use of approved products, as stipulated by the "Code of practice for the use of dispersants" adopted by the Contracting Parties to the Barcelona Convention (cf. RIS/A or RIS/D/2).

Charts clearly showing the boundaries for the use of dispersants in national territorial waters should be prepared and attached to local, district and national plans respectively.

Equipment and products - it is indispensable that a CP lists all **specialized** equipment and products for combating pollution available in the area covered by the plan, and to identify locations in which these are stored. Ideally, it should actually anticipate the most adequate places for stockpiling and procedures for mobilizing these resources. These comprises State owned equipment and products, and those owned by the industry and by other parties from public and private sectors (clean-up contractors, etc.). List of equipment should include all relevant technical data, capacities, energy requirements, necessary logistic back-up, required number of operators, etc. **Non-specialized** equipment such as vessels, aircraft (fixed wing and helicopters), storage tanks, vehicles, etc., needs also to be listed in contingency plans at all levels. Local contingency plans, in particular, should not neglect certain less obvious (non specific) "combating" equipment: shovels, rakes, buckets, ropes, anchors, trucks, vacuum tanks, etc.

Guidelines and arrangements for regular **maintenance** and **testing** of equipment specifically built for oil combating should be included in local plans.

Arrangements for **mobilization** in case of emergency of equipment and products owned by public sector and private persons should be made and this should be indicated in local, district and national plans. As far as products for pollution control (e.g. dispersants, sorbents, etc.) are concerned, it is impractical to keep in stock large quantities of such products and accordingly modalities for their fast **replenishment** have to be identified and indicated in respective plans.

<u>In principle, all response operations will rely upon human resources, equipment and products available at local level (**Tier 1**)</u>. If case of a bigger incident, resources from several localities within the same area will be combined under the overall command of higher (**Tier 2**) authorities.

However, if the combined capacity of pollution response resources available in a particular district through local sources is estimated to be insufficient for the maximum envisaged spill size, it is possible to plan procurement of additional stocks of equipment and products for responding to major accidents by either the State or by the oil industry.

These additional equipment and products can either be stored in centralized, district warehouses or alternatively, these can be distributed among local pollution response authorities in the areas where local stocks are deficient. Decision on who will be responsible for these reserves will largely depend upon the source for funding its purchase.

Manpower - each local plan has to define the required number of operators (and their qualifications, experience, etc.) for anticipated response operations. Logistic back-up for the workers: food, drinks, accommodation, protective clothing, first aid, transportation, etc., should be covered in detail in local plans. Massive oil spill accidents will usually require more manpower that local authorities responsible for pollution combating operations can provide alone and accordingly district plans have to identify additional sources of manpower and conditions for their mobilization.

National contingency plan has to include arrangements for engagement of military personnel, civil defence personnel and other personnel at governmental disposal, whose assistance might be envisaged in case of a major accident of catastrophic proportions. Such arrangements need also to be indicated in district plans.

Transport, storage and disposal of collected oil and oiled material deserve particular attention in each contingency plan. These operations should be carefully studied and most adequate solutions elaborated in (operational part of) each local plan. Traffic routes for evacuation of collected oil, locations for temporary storage and final disposal methods and sites should be determined and described or rather plotted on maps forming a part (annex) of it. District plans have to identify available disposal sites inside each district, while the national plan should set criteria for their selection for the whole country.

Alerting, communications and certain other topics which were mentioned earlier should also be considered as a part of spill response operations and reference to the relevant information should be attached to this part of each Tier 1 and Tier 2 plan.

TRAINING AND EXERCISES - in addition to the initial training, all designated oil spill response personnel should be regularly trained according to their respective anticipated levels of involvement in response operations.

In principle, these levels include: (a) planning / decision-taking, (b) co-ordination / supervision and (c) equipment handling. Periodicity and type of training should be defined in each CP, while local and district plans should comprise more detailed timetables of envisaged training activities. For the personnel who had received initial training adequate for their envisaged role in spill response, it will be only necessary to organize periodical refresher courses. New personnel, included in the spill response organization at a later stage and not adequately trained, will need to be trained either at purposely organized national training courses or through regional training programme prepared by REMPEC. Co-operation in the field of training should be established with the oil industry and with international organizations (governmental, such as International Maritime Organization, or non-governmental).

Instruction manuals for specific topics and for various units forming part of the national pollution preparedness and response system can be prepared at the later stage to give more information on those specific subjects (e.g. containment with booms, manual recovery of oil on beaches, cleaning of oiled birds, disposal methods, etc.). These should not be integral parts of the plan but rather support documents attached to respective local or district plans.

Organizing periodical "paper" and full-scale "simulation" exercises should be planned at regular intervals and the programme of these exercises has to be included in local, district and national plans. Exercises should include testing of all components of the plan (alerting, communications, decision taking, response operations, maintenance, co-ordination of various structures).

UPDATING – provisions concerning the updating of the plan on the basis of new developments and analysis of exercises and pollution incidents (as described in Section 3.2) should be included in each contingency plan.

The plan should also define each local pollution response authority's responsibility for routine updating of annexes and for informing higher authorities (district, national) of any such changes. This refers in particular to annexes containing information liable to change from time to time (names of responsible officers, telephone, telex or fax numbers, stockpiles of equipment or products).

In order to make the updating of contingency plans (national, district, local) as practical as possible, it is advisable keep these documents in **loose-leaf format**.

3. PREPATATION OF CONTINGENCY PLANS

Preparation of contingency plans should start once the required organization for preparedness and response has been set up either at national or at local level, or on the other hand at the level of the company, port or oil terminal.

The responsibility for the preparation of contingency plans is usually distributed, taking also into account the size of accident, either (a) on a geographical basis (in accordance with the administrative division of the country), or (b) on the basis of hierarchy (in accordance with the administrative hierarchy, taking into account seniority in decision-making).

This approach would lead to the preparation of:

a) various **local contingency plans** for relatively small spills and for different coastal localities, offshore or onshore installation (**Tier 1**);

b) a limited number of **district contingency plans**, for medium size spills, which will actually form the backbone of the national pollution preparedness and response system (**Tier 2**);

c) the **national contingency plan**, for large oil spills, which will summarize the adopted policy and strategy and provide for the support of district response arrangements when the magnitude of the problems caused by a pollution accident calls for co-ordination from the highest national level or even for international co-operation (**Tier 3**).

The work at all three levels could be carried out simultaneously and should be co-ordinated by a central or national co-ordinating body.

Local plans for small spills (**Tier 1**) will be prepared either by local public authorities (for localities under their jurisdiction) or by the industry (for the installations operated by them). It is indispensable that all such local plans are prepared as soon as possible, in order to provide background information necessary for contingency planning at higher levels. Local authorities should adhere to the deadlines given to them and submit their draft plans to respective district authorities in stipulated time.

Once the local plans have been prepared, they need to be subsequently revised and checked for compatibility by higher (district) authorities and then integrated into the respective district plans. These in turn should be submitted for verification to the national co-ordinating body.

District plans should be prepared for larger spills (**Tier 2**) either by district authorities (e.g. governors, district harbour masters, district naval commanders, etc.) or by the industry. These plans are aimed at dealing with spills whose size exceeds local capacities or which occur in areas not directly covered by local plans. Tier 2 plans have to provide for overall command and co-ordination of response activities, which will be executed by local spill responders supported, if necessary, by additional resources from industry or from national reserves.

At this stage it will also be necessary to set up a structure (qualified experts from industry and relevant district administrations) for assisting those responsible in taking proper decisions concerning spill response.

If the assessment of risk and the assessment of response capacities show that locally available resources might not be sufficient for envisaged spill risk, it will be necessary to plan the establishment of district stockpiles of equipment and products to support locally available means in cases of bigger accidents. Combining human resources (included or not in local arrangements) from various localities in each district should also be envisaged in district plans.

Financial arrangements for financing any foreseeable or unforeseeable expenses must be agreed upon.

The highest level (**Tier 3**) of co-ordination of resources available in the country, either owned by industry or by national authorities and services, will be provided for by the **national plan** dealing with general policy, description of the organization, assessment of risk at the national level, fate and behaviour of potential spills, definition of priorities for protection, assessment of training needs on all levels of response and questions related to international co-operation, financial arrangements, legal issues, liability and compensation.

During the preparation of all these plans, it should be borne in mind that before their eventual completion and adoption, these will need to be discussed and subsequently modified, and consequently, in order to permit such modifications, each draft should be flexible.

It is also useful that during drafting of various plans contacts are made with the representatives of other interested parties who might not be directly involved in planned response operations, but whose comments could be valuable (e.g. fishermen, operators of tourist complexes, associations for conservation of nature, etc.).

The draft documents will necessarily have to be discussed with all the parties playing a role in their future implementation. Except for obvious contacts with each party separately, it is useful to organize at the final stage of the preparation of the national contingency plan, a (national) meeting for a limited number of key people, representing each department, company, institution or other entity included in the plan. Such a meeting will ensure that all the participants are given the same basic information on the final draft. At the same time, some minor corrections can be made and the participants can reach an agreement on certain pending administrative and technical matters.

The phase of preparation and discussion of the draft NCP and other related plans can be relatively long, however, it seems realistic to expect the draft to be finalized six to twelve months after the setting-up of appropriate preparedness and response organization within the country.

Preparation of the national contingency plan and other relevant plans has to be complemented with training, aiming in particular at **On-Scene Commanders** and/or **supervisors** i.e. persons who had been designated to direct and co-ordinate spill response operations. In distinction from decision-makers, On-Scene Commanders should be trained mainly in operational, technical and logistic aspects of oil pollution response.

3.1 Approval and implementation of the provisions of a plan

In order to be implemented, the NCP has to be approved following a standard national procedure for this type of documents. Once the responsible authority has granted its approval, the Plan can start its legal existence.

The implementation phase is of major importance and without it all the work done previously would have been of no avail. The full implementation of the NCP will however require two more important steps to be taken. On the statutory level, all relevant texts containing definitions of national policy, organizational structures, distribution of responsibilities and other issues of general national interest that had been approved at national level, need to be officially published and distributed to the parties concerned. On the technical level, the means for the implementation of the Plan have to be set up. Regarding the latter, it is necessary to establish, during the preparation of the Plan, whether the means (equipment, products) for pollution response already existing in the country are sufficient for dealing with the maximum probable spill envisaged by the Plan, and whether their location is appropriate with regard to envisaged priorities for protection / response. The negative answer to any of these questions will necessitate procurement of additional means either by a state agency (government) or by the industry, depending on the policy adopted by each particular country.

If its implementation does not involve procurement of additional equipment and products, the provisions of the national contingency plan can be fully implemented almost as soon as it has been approved or at the worst a few weeks from that date. On the other hand, if it is necessary to acquire additional resources, this phase may last a year or even more, depending on financial arrangements made.

However, deficiency of pollution response material should under no circumstances block the implementation of other provisions of the national contingency plan. If necessary, the procurement in several phases of additional equipment and/or products should be considered.

The phase of implementation of the national contingency plan and other respective subordinate plans also needs to be complemented by the adequate level of training. At this stage, the effort should focus on **training operators**, or rather the leaders (foremen) of operational response teams. These persons will normally be employees of refineries, power plants, ports, terminals, etc. whose daily work will not be exclusively related to pollution response. However, when an oil spill occurs they will be directly engaged in containment and recovery of oil at sea or on shore, application of dispersants or other treatment products, shore clean-up operations and disposal of collected oil and oily material. In addition, they will be responsible for regular maintenance of the response equipment.

3.2 Testing, updating and reviewing the Plan

The process of contingency planning, regardless of its level, should be considered as a continuous process and not merely as preparing and finalizing a certain document. Each plan needs permanent improvement on the basis of new developments and changing circumstances. The most important source of information on what needs to be changed and modified should be exercises. Periodically, exercises should be organized at local, national or international level, during which all elements of the plan or only its segments (e.g. communications, alerting procedures, mobilization of personnel and equipment, etc) are tested. In addition, each accident should be considered as an excellent opportunity to verify the functioning of the complete national system for preparedness and response and the contingency plan in particular. All the events and especially critical situations or procedures which did not give expected results should be analyzed as soon as possible after the accident and all necessary improvements should be subsequently entered into the national contingency plan and / or local plans supporting it.

3.3 International co-operation

Only after a national preparedness and response system is set up and the provisions of the national contingency plan are implemented, the country will be ready to fully co-operate with neighbouring countries (also having their NCP) in the field of preparedness and response to accidental marine pollution. It is very important that the implications of possible international co-operation are borne in mind from the earliest stages of setting up the national system. Provisions regarding international co-operation should be built in it if the smooth fitting of the country concerned into an international system for mutual assistance (such as provided by the Emergency Protocol to the Barcelona Convention) is aimed at. At a later stage, such co-operation may result in the adoption of bilateral or multilateral arrangements providing for exchange of information, harmonization of legal procedures and mutual assistance in cases of accidents.

Chapter 4

COMMUNICATIONSS AND REPORTING

1. INTRODUCTION

Communications related to oil spill preparedness and response includes two different categories of communications. In chronological order these are:

1. transmission to the authority competent to deal with marine pollution incidents of information on occurrence of an oil spill or an accident likely to cause it;

2. all communications during spill response operations.

Proper planning and making standing arrangements for both categories are equally important for a successful outcome of marine pollution response activities.

Information concerning an accident or a spill has to be transmitted, received and disseminated to all interested parties as quickly as possible, however this will only be possible if two systems are in place. These are a reliable **communications system** and a well-established **reporting system**.

Using the terminology of the information technology, the first one can be considered as the "hardware" and the second one as the "software".

Communications system includes various means of communications, i.e. equipment for transmission and reception of information, while reporting system comprises a number of standardized procedures for communicating relevant information.

Both systems are closely related and one can hardly effectively operate without the other. Very common misconception is that the communication system plays the most (and only) important role. Unfortunately, existence of even the most sophisticated equipment does not guarantee proper exchange of information in case of marine pollution emergency if the procedures for transmission of information are not prepared in advance and well understood by the persons concerned.

2. COMMUNICATION SYSTEM

A number of communications means are available either for the transmission of alert messages or notifications on an accident or for the exchange of messages once the response activities have started. These include radio, telephone (fixed or cellular, mobile), telex, fax and the equipment for electronic data exchange (e.g. e-mail).

Initial reports on accidents could be reported to the nearest authority using any available means. If an accident occurs offshore, it is likely that the notification will be transmitted to the authorities from a ship (or sometimes from an aircraft) by radio using one of allocated marine or aeronautical VHF bands. If the initial report is made from land, literally any available means could be used, however messages are most often transmitted through public telephone networks.

A list communications means that can be used for the transmission of accident reports, alert messages, and later on for the message traffic related to response activities includes:

VHF - FM Marine (156 - 158 MHz)	ship - ship ship - shore	line of sight
VHF - AM Aircraft (118 - 136 MHz)	aircraft - aircraft aircraft - land	line of sight
UHF Oil Spill (151 - 459.000 MHz)	land - land (land - sea, land - air)	line of sight
HF - SSB (2 - 20 MHz)	ship - ship ship - shore	30 - 50 Nm
Cellular telephones	ship - land - air	within area served
Inmarsat	ship - ship ship - land	world wide
Fax, telex, E-data	anywhere (fixed, mobile)	world wide

A number of technical requirements concerning in particular radio communications, that are most often used for transmission of messages related to the accident and the casualty, have been developed and are regularly updated by the relevant bodies of the International Maritime Organization (IMO) and International Telecommunications Union (ITU).

Once the initial messages regarding the accident, the casualty, search and rescue operations, etc have been transmitted, and the decisions concerning spill response activities have been taken, the message traffic mainly concerns the exchange of **information relevant for the response operations**.

These are often divided in long, medium and short distance communications.

Long distance communications include all contacts between operations' headquarters (Emergency Response Centre) and various competent national authorities and international organizations and companies involved in spill response. Existing public telephone (both fixed and mobile), fax and telex networks are all used for such contacts.

- **Fax** and **telex** leave written records and are therefore recommended.

- **Electronic data exchange** (e-mail), becoming increasingly common in recent years, might not be as reliable as traditional means, in particular in those parts of the world where the relevant networks are not completely trustworthy.

Medium distance communications concern routine contacts with local authorities, spill clean up contractors, companies, press and other parties involved in spill response operations that are based in the vicinity of the affected area or the Emergency Response Centre. For the reasons of practicality these types of communications are usually made by telephone.

- The **public telephone system** is usually sufficient, however it is extremely useful to have several lines at the response centre with a view to ensuring that not all the lines are permanently occupied.

- The use of **cellular phones**, if the area is covered by the service, may largely help in this respect.

In planning the operations it is important to understand that one or two lines will be almost all the time occupied by the public relations officer and his contacts with the press, thus rendering these lines useless for "operational" contacts. Accordingly, one or two other lines should be dedicated strictly to the message traffic related to the operations, and the respective numbers should not be revealed to suppliers of equipment, press, etc. If the written record is required, even in operational communications the use should be made of fax or telex.

Short distance communications are those between the response centre and the field response teams, surveillance aircraft and the response centre, the centre and various work teams' leaders, vessels involved in the operations, dispersant spraying vessels and spotter aircraft, between the members of the same response team, etc. These are normally carried out by using VHF and UHF portable radios, however if a public cellular telephone network covers the area where the operations are taking place, mobile phones can largely facilitate the communications.

Radio frequencies/channels available for use in spill response operations may vary from country to country, and it is essential to precisely define such frequencies during the contingency planning process. Those specifically allocated for use in spill response communications should be listed in the (national) contingency plan. This will ensure that in case of emergency any interference from other sources is eliminated to the maximum extent possible. The channels for the VHF services are listed in the (international) Radio Regulations, Appendix 18. There are 59 channels and the Appendix indicates different frequencies and services. In the European Maritime area and in Canada channels 10, 67 and 73 may be used, if so required, by the individual administrations concerned, for communications between ship stations, aircraft stations and participating land stations engaged in co-ordinated search and rescue operations and for communication in pollution response operations in local areas. All **fixed** and most **portable VHF** equipment usually have all Appendix 18 channels, so equipment for on scene communications should have at least 6 channels that could be used in transmitting pollution response related messages. In addition to channels 10, 67 and 73, inter-ship and distress/safety channels 6, 8 and 16 can also be utilized, always taking into consideration other priorities allocated to these channels.

When the Emergency Response Centre is not located close to the sea and equipped with suitable radio communication equipment, existing **coast radio stations** may be used instead of establishing separate stations only for pollution response operations. If the spill response operations are carried at sea, outside of the VHF range, but within the range of at least one of the MF stations, the on-scene commander unit should be equipped with MF equipment capable of operating on all channels dedicated to oil combating purposes in the different countries in addition to 2182 kHz.

Topography of the zone of operations may cause difficulties in radio communications, however this can be avoided by the use of aerials, or if this is not possible, vessels can act as relays.

All communication facilities (fixed and mobile telephones, faxes, telexes, pagers, fixed and mobile radio stations, handsets, etc) together with their respective numbers and frequencies or channels should be listed in the contingency plan (local, national, bilateral, subregional) and always kept updated in order to avoid any unnecessary waste of time when an accident occurs.

3. REPORTING

The **obligation** to report maritime accidents, in particular those causing or likely to cause pollution of the sea, exist under various international conventions with global coverage, including SOLAS, MARPOL and OPRC, as well as at the regional level e.g. under the Emergency Protocol to the Barcelona Convention. The principal objectives of pollution reports are:

- to provide data on unlawful discharges of hazardous substances;
- to provide data on an incident at sea without delay, with a view to initiate the appropriate response;
- to update these data and adapt the response to the actual situation; and
- to provide reports to coastal states which may be concerned by the incident, or may provide additional means of response.

As soon as an authority becomes aware of a marine pollution accident it should immediately alert relevant authorities of the nearest coastal state (or states) through its designated office. These may include a specialised pollution response or control organization, Emergency Response Centre, maritime authorities, Harbour Master's office, Coast Guard, police, navy, port authorities, district fisheries authorities, civil protection department, etc. Competent national authorities of the Mediterranean coastal States, to whom reports on incidents should be transmitted, are listed in document RIS/B/1.

Any communication means can be used at this stage, however a written communication is preferred to voice communication.

Procedure for transmitting alert messages should be described and explained in detail in the national contingency plan and competent national authority should make sure that all potential reporters are fully aware of and familiar with the envisaged procedure. It is of paramount importance that all relevant offices and services are precisely instructed on how to transmit an alert message to the authority responsible for responding to marine pollution accidents.

Verification of the initial report should be made either by the first office or organization receiving an alert message or by the national authority responsible for the activation of the (local or national) contingency plan.

The decisions made by the competent authorities, including those on the type and extent of the response activities depend directly upon the contents of the information received. It is therefore necessary that the message transmitted contain sufficient information on which the decision-makers can base their decisions.

The **contents and form** of pollution reports often vary from one place or country to another, and with a view to standardizing pollution reports and alert messages various forms of reports were proposed and/or adopted in different countries or regions. Regardless of differences among them each report should contain at least the following information:

1. Source of information
2. Date and time of the event (accident)

3. Position of the event
4. Source of pollution
5. Type of pollutant
6. Size of pollution and its description
7. Meteorological conditions in the area
8. Oceanographic/hydrodynamic data
9. Actions already taken
10. Endangered areas

Contracting Parties to the Emergency Protocol to the Barcelona Convention adopted for use in the Mediterranean region, when reporting marine pollution accidents to each other, a pollution reporting format recommended by the International Maritime Organization (IMO) that is known as **POLREP**. A detailed description of the POLREP Pollution Reporting System is given in Annex 1 to this Chapter.

The **quality** of the transmitted information plays an extremely important role in reporting marine pollution accidents. It will vitally influence decision-making process, and the outcome of the entire operation may depend on it. Ideally, and as much as possible the information contained in the report
should be:

- **prompt** - in cases of a marine pollution emergency time is an extremely important factor. A delay in forwarding the initial information will of course result in a delayed start of the intervention, and it has been proven that the shorter the delay of response to an oil spill is, easier will be to remove the oil, the cost of the operation will be cheaper, less coastline is likely to be affected, less pollutant will be lost to the environment, etc.

- **accurate** - data communicated to the responsible authority should correspond to the actual (true) situation, and any assumptions or speculations may result in taking a wrong decision.

- **precise** - if more than one message is sent, these should be fully compatible. Particular attention should be paid to the units used, names of vessels or persons involved, etc.

- **complete** - the message should contain as much data as available at the time of transmitting the information. Additional information should be transmitted as soon as it becomes available.

- **brief** - besides being complete, the message should be brief. It may be difficult to transmit long messages because of the restrictions of the communication system. Using figures is more useful for decision-makers than sending long descriptions and "stories".

The above notes are relating to initial information on a marine pollution accident (alert message, notification). Once the response operations have started, the exchange of information between the emergency response centre and field teams, various authorities and organizations involved will become very frequent. If it was possible to formulate a standard reporting format suitable for any pollution accident, it is certainly not possible to standardize the format for exchange of information during the response operations, mainly due to their variety in both contents and form. However it might be useful to try to apply the same notions on the quality of any information communicated between various interlocutors involved in response operations. Messages formulated in such a way will help in planning the activities and taking appropriate decisions.

ANNEX

P O L R E P

POLLUTION REPORTING SYSTEM

Mediterranean coastal States, contracting Parties to the Emergency Protocol, committed themselves to inform each other, either directly or through the Regional Centre on:

(a) all accidents causing or likely to cause pollution of the sea by oil and other harmful substances;

(b) the presence, characteristics and extent of spillages of oil or other harmful substances observed at sea which are likely to present a serious and imminent threat to the marine environment or to the coast or related interests of one or more of the Parties;

(c) their assessments and any pollution combating actions taken or envisaged to be taken;

(d) the evolution of the situation.

Moreover, each Party needing the assistance may request it from the other Parties either directly or through the Centre.

A standard pollution accidents reporting format is used in order to facilitate rapid transmission of information and requests for assistance.

The following format of the standard alert message, to be used within the framework of the Emergency Protocol, has been recommended by the International Maritime Organization (IMO) with a view to harmonizing pollution reporting systems.

POLLUTION REPORTING SYSTEM (POLREP)

1 The pollution reporting system is for use between Contracting Parties to the Emergency Protocol of the Barcelona Convention themselves and between the Contracting Parties and the Regional Centre, for exchanging information when pollution of the sea has occurred or when a threat of such is present.

2 The POLREP is divided into three parts:

.1	Part I or POLWARN (figures 1-5)	POLlution WARNing	gives first information or warning of the pollution or the threat
.2	Part II or POLINF (figures 40-60)	POLlution INFormation	gives detailed supplementary report as well as situation reports
.3	Part III or POLFAC (figures 80-99)	POLlution FACilities	is used for requesting assistance from other Contracting Parties and for defining operational matters related to the assistance

3 A summarized list of POLREP is given below.

	Address	from	to ....
INTRODUCTORY PART	Date Time Group		
	Identification		
	Serial number		

PART I (POLWARN)	1	Date and time
	2	Position
	3	Incident
	4	Outflow
	5	Acknowledge
PART II (POLINF)	40	Date and time
	41	Position
	42	Characteristics of pollution
	43	Source and cause of pollution
	44	Wind direction and speed
	45	Current or tide
	46	Sea state and visibility
	47	Drift of pollution
	48	Forecast
	49	Identity of observer and ships on scene
	50	Action taken
	51	Photographs or samples
	52	Names of other States informed
	53-59	Spare
	60	Acknowledge
PART III (POLFAC)	80	Date and time
	81	Request for assistance
	82	Cost
	83	Pre-arrangements for the delivery
	84	Assistance to where and how
	85	Other States requested
	86	Change of command
	87	Exchange of information
	88-98	Spare
	99	Acknowledge

EXPLANATION OF A POLREP MESSAGE

INTRODUCTORY PART

Contents	Remarks
ADDRESS	Each report should start with an indication of the country whose competent national authority is sending it and of addressee e.g.: FROM: ITA (indicates the country which sends the report) TO: GRC (indicates the country to which it is sent) or REMPEC (indicates that the message is sent to the Regional Centre).
DTG (Day Time Group)	The day of the month followed by the time (hour and minute) of drafting the message. Always a 6-figure group which may be followed by month indication. Time should be stated either as GMT, e.g. 092015Z june (i.e. the 9th of the relevant month at 20.15 GMT) or as local time e.g. 092115LT june.
IDENTIFICATION	"POL..." indicates that the report might deal with all aspects of pollution (such as oil as well as other harmful substances). ".....REP" indicates that this is a report on a pollution incident. It can contain up to 3 main parts: Part I (POLWARN) - is an initial notice (a first information or a warning) of a casualty or the presence of oil slicks or harmful substances. This part of the report is numbered from 1 to 5. Part II (POLINF) - is a detailed supplementary report to Part I. This part of the report is numbered from 40 to 60. Part III (POLFAC) - is for a requests for assistance from other Contracting Parties, as well as for defining operational matters related to the assistance. This part of the report is numbered from 80 to 99. BARCELONA CONVENTION indicates that the message is sent within the framework of the Emergency Protocol to the Barcelona Convention. Parts I, II and III can be transmitted all together in one report or separately. Furthermore, single figures from each part can be transmitted separately or combined with figures from the two other parts. Figures without additional text shall not appear in the POLREP. When Part I is used as warning of a serious threat, the message should be headed with the traffic priority word "URGENT". All POLREPs containing ACKNOWLEDGE figures (5, 60 or 99) should be acknowledged as soon as possible by the competent national authority of the country receiving the message.

POLREPs should always be terminated by a fax or telex from the reporting State, which indicates that no more operational communication on that particular incident can be expected.

SERIAL NUMBER

Each single report should be possible to identify and the receiving agency should be in a position to check whether all reports of the incident in question have been received. This is done by using a nation-identifier:

Albania	ALB	Lebanon	LBN
Algeria	DZA	Libya	LBY
Bosnia & Herzegovina	BIH	Malta	MLT
Croatia	HRV	Monaco	MCO
Cyprus	CYP	Morocco	MAR
EU	EU	Slovenia	SLO
Egypt	EGY	Spain	ESP
France	FRA	Syria	SYR
Greece	GRC	Tunisia	TUN
Israel	ISR	Turkey	TUR
Italy	ITA		

Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea — REMPEC

The nation-identifier should be followed by a stroke and the name of the ship or other installation involved in the accident and another stroke followed by the number of the actual report concerning this particular accident.

ITA/POLLUX/1 indicates that this is the first report from Italy concerning the accident of MT "POLLUX".

ITA/POLLUX/2, in accordance with the described system, indicates the second report on the same incident.

Part I (POLWARN)

Contents	Remarks
1 DATE AND TIME	The day of the month as well as the time of the day when the incident took place or, if the cause of the pollution is not known, the time of the observation should be stated with 6 figures. Time should be stated as GMT for example, 091900z (i.e. the 9th of the relevant month at 1900 GMT) or as local time for example, 091900lt (i.e. 9th of the relevant month at 1900 local time)
2 POSITION	Indicates the main position of the incident in latitude and longitude in degrees and minutes and may, in addition, give the bearing of and the distance from a location known by the receiver.
3 INCIDENT	The nature of the incident should be stated here, such as BLOWOUT, TANKER GROUNDING, TANKER COLLISION, OIL SLICK, etc.
4 OUTFLOW	The nature of the pollution, such as CRUDE OIL, CHLORINE, DINITROL, PHENOL, etc. as well as the total quantity in tonnes of the outflow and/or the flow rate, as well as the risk of the further outflow. If there is no pollution but a pollution threat, the words NOT YET followed by the substance, for example, NOT YET FUEL OIL, should be stated.
5 ACKNOWLEDGE	When this figure is used the telex should be acknowledged as soon as possible by the competent national authority.

Contents	Remarks
40 DATE AND TIME	No. 40 relates to the situation described in figures 41 to 60 if it varies from figure 1.
41 POSITION AND/OR EXTENT OF POLLUTION ON/ ABOVE/IN THE SEA	Indicates the main position of the pollution in latitude and longitude in degrees and minutes and may in addition give the distance and bearing of some prominent landmark known to the receiver if other than indicated in figure 2. Estimate amount of pollution (e.g. size of polluted areas, number of tonnes of oil spilled if other than indicated in figure 4, or number of containers, drums etc. lost). Indicates length and width of slick given in nautical miles if not indicated in Fig. 2.
42 CHARACTERISTICS OF POLLUTION	Gives type of pollution, e.g. type of oil with viscosity and pour point, packaged or bulk chemicals, sewage. For chemicals give proper name or United Nations number if known. For all, give also appearance, e.g. liquid, floating solid, liquid oil, semi-liquid sludge, tarry lumps, weathered oil, discolouration of sea, visible vapour. Any markings on drums, containers, etc. should be given.
43 SOURCES AND CAUSE OF POLLUTION	For example, from vessel or other undertaking. If from vessel, say whether as a result of a deliberate discharge or casualty. If the latter, give brief description. Where possible, give name, type, size, call sign, nationality and port of registration of polluting vessel. If vessel is proceeding on its way, give course, speed and destination.
44 WIND DIRECTION AND SPEED	Indicates wind direction and speed in degrees and m/s. The direction always indicates from where the wind is blowing.
45 CURRENT DIRECTION AND SPEED AND/OR TIDE	Indicates currents direction and speed in degrees and m/s. The direction always indicates the direction in which the current is flowing.
46 SEA STATE AND VISIBILITY	Sea state indicated as wave height in metres. Visibility in nautical miles.
47 DRIFT OF POLLUTION	Indicates drift course and speed of pollution in degrees and knots and tenths of knots. In case of air pollution (gas cloud) drift speed is indicated in m/s.
48 FORECAST OF LIKELY EFFECT OF POLLUTION AND ZONES AFFECTED	For example, arrival on beach with estimated timing. Results of mathematical models.

Contents	Remarks
49 IDENTITY OF OBSERVER/REPORTER IDENTITY OF SHIPS ON SCENE	Indicates who has reported the incident. If a ship, name, home port, flag and call sign must be given. Ships on scene can also be indicated under this item by name, home port, flag and call sign, especially if the polluter cannot be identified and the spill is considered to be of recent origin.
50 ACTION TAKEN	Any action taken in response to the pollution.
51 PHOTOGRAPHS OR SAMPLES	Indicates if photographs or samples from the pollution have been taken. Fax or telex number of the sampling authority should be given.
52 NAMES OF OTHER STATES AND ORGANIZATIONS INFORMED	
53 - 59	SPARE FOR ANY OTHER RELEVANT INFORMATION (e.g. results of sample or photographic analysis, results of inspection of surveyors, statements of ship's personnel, etc.)
60 ACKNOWLEDGE	When this figure is used the telex should be acknowledged as soon as possible by the competent national authority.

Part III (POLFAC)

Contents	Remarks
80 DATE AND TIME	No. 80 is related to the situation described below, if it varies from figures 1 and/or 40.
81 REQUEST FOR ASSISTANCE	Type and amount of assistance required in form of: - specified equipment - specified equipment with trained personnel - complete strike teams - personnel with special expertise with indication of country requested.

82 COST	Requirements for cost information to requesting country of delivered assistance.
83 PRE-ARRANGEMENTS FOR DELIVERY OF ASSISTANCE	Information concerning customs clearance, access to territorial waters, etc. in the requesting country.
84 TO WHERE ASSISTANCE SHOULD BE RENDERED AND HOW	Information concerning the delivery of the assistance, e.g. rendez-vous at sea with information on frequencies to be used, call sign and name of supreme on-scene commander of the requesting country, or land-based authorities with telephone, telex and fax numbers and contact persons.
85 NAMES OF OTHER STATES STATES AND ORGANIZATIONS	Only to be filled in if not covered by figure 81, e.g. if further assistance is later needed by other States.
86 CHANGE OF COMMAND	When a substantial part of an oil pollution or serious threat of oil pollution moves or has moved into the zone of another Contracting Party, the country which has exercised the supreme command of the operation may request the other country to take over the supreme command.
87 EXCHANGE OF INFORMATION	When a mutual agreement has been reached between two parties on a change of supreme command, the country transferring the supreme command should give a report on all relevant information pertaining to the operation to the country taking over the command.
88 - 98	SPARE FOR ANY OTHER RELEVANT REQUIREMENTS OR INSTRUCTIONS
99 ACKNOWLEDGE	When this figure is used the message should be acknowledged as soon as possible by the competent national authority.

POLREP
Example No.1
Full Report (Parts I, II and III)

Address		From:	ITA
		To:	FRA and REMPEC
Date Time Group		181100z june	
Identification		POLREP BARCELONA CONVENTION	
Serial number		ITA/POLLUX/2 (ITA/POLLUX/1 for REMPEC)	

1	Date and time	1	181000z
2	Position	2	43°31'N - 09°54'E
3	Incident	3	Tanker collision
4	Outflow	4	Crude oil, estimated 3000 tonnes

41	Position and/or extent of pollution on/above/in sea	41	The oil is forming a slick 0.5 nautical miles to the south-west. With up to 0.3 nautical miles.
42	Characteristics of pollution	42	Venezuela crude. Viscosity 3780 cSt at 37.8°C. Rather viscous.
43	Source and cause of pollution	43	Italian tanker POLLUX of Genoa, 22000 GRT, call sign xxx in collision with French bulk carrier CASTOR of Marseille, 30000 GRT, call sign yyy. Two tanks damaged in POLLUX. No damage in CASTOR.
44	Wind direction and speed	44	90 - 10 m/s.
45	Current direction and speed and/or tide	45	180 - 0.3 knots.
46	Sea state and visibility	46	Wave height 2 m. 10 nautical miles.
47	Drift of pollution	47	240 - 0.5 knots.
48	Forecast of likely effects of pollution and zones affected	48	Could reach Corsica, FRA on the 21st of this month
49	Identity of observer/reporter Identity of ships on scene	49	CASTOR, figure 43 refers.
50	Action taken	50	3 Italian antipollution vessels with high oil recovery and dispersant spraying capacity on route to the area.
51	Photographs or samples	51	Oil samples have been taken. Fax 123456 XYZ ITA.
52	Names of other States and organizations informed	52	REMPEC
53	Spare	53	Italian national contingency plan is activated.

81	Request for assistance	81	FRA is requested for 1 surveillance aircraft with remote sensing equipment.
82	Cost	82	FRA is requested for an approximate cost rate per day of assistance rendered.
83	Pre-arrangements for the delivery of assistance	83	FRA plane will be allowed to enter Italian air space for spill surveillance and Italian airports for logistics, informing OSC beforehand.
84	To where assistance should be rendered and how	84	Rendez-vous 43°15'N - 09°50'E. Report on VHF channels 16 and 67. OSC, Comm. Rossi in M/V SAN MARCO call sign xxx.
99	Acknowledge	99	ACKNOWLEDGE

POLREP
Example No. 2
Abbreviated Report (Single figures from Part III)

Address		From:	FRA
		To:	ITA
Date Time Group		182230z june	
Identification		POLREP BARCELONA CONVENTION	
Serial Number		Your ITA/POLLUX/2	
80	Date and Time	80	182020z
82	Cost	82	Total cost per day will be approx...
84	To where assistance should be rendered and how	84	ETA FRA unit at POLREP BARCELONA CONVENTION ITA/POLLUX/2 will be 190700z.

POLREP
Example No. 3
Exercise Report

Address		From:	ITA
		To:	CRT
Date Time Group		210940z june	
		URGENT	
		EXERCISE	
Identification		POLREP BARCELONA CONVENTION	
Serial Number		Your ITA/xxx/1	
1	Date and Time	1	210830
2	Position	2	44°50'N - 13°02'E
3	Incident	3	Tanker collision
4	Outflow	4	Not yet
5	Acknowledge	5	Acknowledge
			EXERCISE EXERCISE EXERCISE

Chapter 5

GUIDELINES FOR OBSERVATION AND REPORTING OIL SPILLS (AERIAL SURVEILLANCE)

1. INTRODUCTION

Aerial surveillance of oil spills is made either from helicopters or from fixed-wing aircraft. It could be made using sophisticated remote sensing equipment, however **visual aerial observation** is often the most convenient means of assessing oil pollution at sea and on shore, which if properly carried out, can give an important indication, sometimes of a decisive nature, concerning:

- the extent of pollution (overall surface totally or partly covered);
- the evolution of pollution and its follow-up;
- the quantity of floating oil;
- the evaluation of the threat;
- the selection of appropriate combating techniques;
- the evaluation of the effectiveness of means used;
- the assessment of damage.

Unfortunately, aerial surveillance is in most cases done by personnel not specifically trained in this activity (pilots, photographers, aerial navigators), which in turn often results in unreliable and inaccurate reports. In order to ensure that the information provided by observers is precise and quantifiable enough to be of use for the authorities responsible for pollution combating, an attempt has been made to prepare a set of basic instructions for observers and to standardize the terminology used in reports.

The objectives of this Chapter are to give guidelines to non-specialized observers on how:

- to know what to look for;
- to know to locate the pollution;
- to observe, describe and report the pollution;
- to prepare the information for further processing.

2. ORGANIZATION OF AN AERIAL OBSERVATIO MISSION

- The aircraft (either helicopter or fixed-wing) chosen for aerial surveillance of oil spills should have **good all round visibility**.

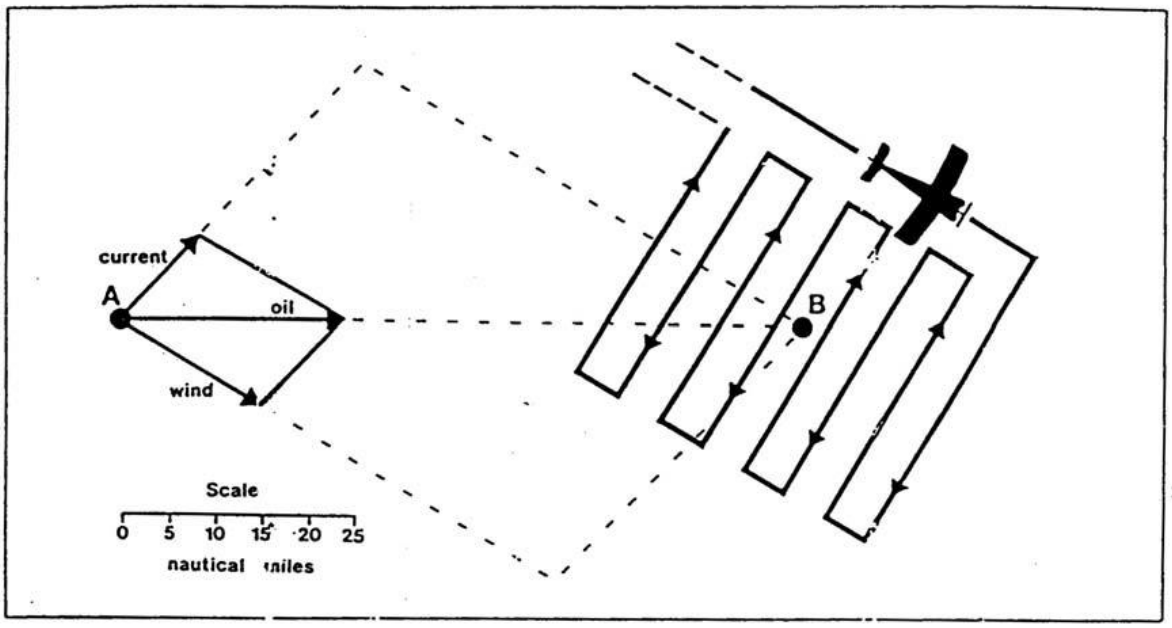
- **Helicopters** are more suitable for missions **near the shore**, while **fixed-wing aircraft** provide more speed and longer range for missions over the **open sea**.

- **Safety** of the crew and observers must always supersede all other considerations and therefore **multi-engine** (at least twin) **aircraft** should be used for all missions over remote sea areas.

- In order to reduce as much as possible the time spent searching for pollution, a **flight plan** should be prepared before the flight.

- Observers should be provided with the **charts** of the area. For more accurate identification of positions and reporting, it is useful to draw a **grid** on the chart using e.g. grid squares with the sides of 1 Nautical mile each.

- A "**ladder search**" (illustrated on the following page) across the direction of the prevailing wind is considered to be the most efficient method of surveying the area in which the oil might be found. A **systematic search** for oil over a large sea area is recommended since forecasting of oil movement is intrinsically not very accurate, and accordingly oil might be found at larger distances or in directions different from those predicted on the basis of calculation.



Movement of oil from A to position B three days later, predicted by combining 100% of the current speed and 3% of the wind speed as shown. The arrows from A represent current, wind and oil movement for one day. A cross-wind ladder search pattern is shown over position B.

Reproduced from "Response to Marine Oil Spills", International Tanker Owners Pollution Federation Ltd., 1987

- When the visibility is good (in clear weather) a recommended **altitude** is approximately 500 m, however, in order to obtain better view of the oil, once found, it is necessary to drop to lower altitudes (200 m or less).

- In order to determine the **position** of oil sightings, the observer should be able to consult aircraft instruments, in particular when oil is found at open sea, far from shore and points of reference on the shore.

- In order to enable the undisturbed **communication** between the observer and the pilot of the aircraft, wearing of headsets is highly recommended.

- **Sun glasses** (with polarising lenses, if possible) will help detection of oil at sea under certain light conditions.

3. APPERANCE OF OIL SPILLS

When spilled at sea, oil forms a **slick** which drifts with the wind and current, and subsequently breaks up into smaller **slicks (patches)**, usually interspersed with the areas of relatively thin **sheen**, and scatters over areas which, with time, become considerably large. With the changing in wind direction, the refloating of oil already deposited on shores might occur. After being at sea for a certain period oil can be mixed with algae and debris.

Three main groups of oil can be distinguished in accordance with their appearance when floating on the sea surface:

- **Light refined products** (petrol, gas oil, kerosene) which spread uniformly on big surfaces and undergo strong evaporation and rapid natural dispersion processes, often resulting in their total disappearance in 2 to 3 days. They form thin **sheens**.

- **Heavy refined products** (fuel No.6 and most types of fuel oils used by merchant ships) which are very viscous spread less rapidly and do not disappear naturally. These form **dark** thicker patches, separated by areas of intermediate and thin **sheens**.

- **Crude oils** whose characteristics and behaviour vary greatly according to their type and origin. Usually these rapidly break into areas of **dark**, thicker oil interspersed with areas of intermediate and thin **sheens**.

In general terms, the thick parts of an oil slick have **dull (dark)** colours, the colour of patches of intermediate thickness is **blue or iridescent (rainbow)**, and the thinnest parts of a slick appear as areas of **grey or silvery sheen**.

Sheen consists of only small quantities of oil but is the most visible proof of pollution. Frequently, thick patches are discovered in the midst and windward of an area covered by sheen (silver, grey or iridescent).

Thick patches represent big quantities of oil. Generally, **black or dark brown** at the early stages of pollution, most crude oils and heavy refined products, under the influence of sea movement (waves), show a tendency towards formation of water-in-oil emulsions, usually called chocolate mousse, which appear as **brown, red, orange or yellow** patches.

Table 1 gives an indication of relations between the **appearance** (colour) of an oil slick, **approximate thickness** of oil and the **approximate volume** of oil (in cubic metres) the slick contains per unit of surface area (square kilometres).

Table 1. Appearance, thickness and volume of oil on the sea surface

APPEARANCE / COLOUR	APPROX. THICKNESS [μm]	APPROX. VOLUME [m^3/km^2]
silvery sheen	0.02 - 0.05	0
grey sheen	0.1	0.1
iridescent (rainbow) sheen	0.3	0.3
Blue	1.0	1
blue/brown	5.0	5
brown/black	15 - 25	15 - 25
dark brown/black	> 100	> 100
brown/red/orange/yellow mousse	> 1 mm	

Reproduced from "Manual on Oil Pollution at Sea: Securing Evidence on Discharges from Ships", Bonn Agreement, 1993

4. DESCIPTION OF POLLUTION

It is recommended to endeavour to utilize the same observers during each particular pollution incident, in order to minimize disparity in reporting. However, if this is not possible, observers should be instructed to use the following terminology when reporting (describing) oil spills:

a) Sheen:

"light sheen"	sea surface covered with faint silvery sheen, barely visible under favourable light conditions;
"sheen"	sea surface covered with consistent silvery and grey sheen, no patches of thick oil;
"heavy sheen"	sea completely covered with grey sheen, occasionally having rainbow colours (iridescent), no patches of thick oil.

b) Patches:

"small patches"	less than 1 m^2, hardly visible from higher altitudes, ranging in colour from blue and brown to black;
"medium patches"	10 - 100 m^2, clearly visible from the air, colours blue, brown or black.
"big patches"	large slicks of 100 m^2 and over, clearly visible, colours blue, brown or black.

In order to indicate what percentage of the sea area is covered by oil, the observer should describe the slicks as:

"scattered"	if 1 to 2% of the sea is covered;
"not too compact"	if up to 5% of the sea is covered;
"compact"	if up to 20% of the sea is covered;
"very compact"	if over 20% of the sea is covered.

In order to estimate as accurately as possible the percentage area of the sea covered by oil, it is recommended to view vertically down on the sea surface, to time overflying each type of oil (sheen, patch, mousse) at the constant (and recorded) speed of the aircraft, and to calculate the percentages on the basis of these records once the surveillance flight is over.

Big patches should be reported singly. The report should include the colour of the patch and information on (description of) any sheen (iridescence) present around these patches of darker oil. Particular attention should be paid to identifying brownish/red/orange/yellow colours which indicate the presence of chocolate mousse (this is important for the selection of response techniques, since the presence of reverse emulsions excludes the use of certain types of skimmers or dispersants).

If possible, colour or infra-red black and white photographs or slides, or video recording of the slick should complement each report.

5. REMARKS

- Often, up to 90% of oil is concentrated on 10% of the surface covered by a slick, in its downwind end. This phenomenon is more pronounced by cold sea and weather.

- A strong wind, of more than 20 knots, causes formation of separate windrows.

- The absence of iridescence (rainbow colour bands) is almost always an indication of slick weathering and emulsion formation.

- The appearance of a slick can change, depending on the position of the sun in relation to the observer. If there are any doubts, several overflights from different directions should be made in order to verify the initial observation.

- Certain phenomena (shadows of clouds, algae or seaweed under the sea surface, suspended sediments in an estuary) can be mistaken for oil slicks. If there are any doubts, the observer should request additional overflights of the suspicious area.

- During very strong storms (sea 6), even a major pollution can be difficult to notice and it may become visible only once the weather has calmed down (CAUTION: only large multi-engine aircraft could be used for aerial surveillance under such conditions).

6. METEOROLOGICAL CONDITIONS

The influence of meteorological conditions is as decisive for the observation of a spill as it is for its combating. Tables 2, 3 and 4, give standard scales for wind force (Beaufort wind force scale), sea state and nebulosity, respectively, which should be used by observers when reporting meteorological conditions in the surveyed area.

Table 2. Beaufort wind force scale

DESCRIPTIVE TERM	BEAUFORT NUMBER	LIMITS OF WIND VELOCITY		PROBABLE MEAN * HEIGHT OF WAVES in metres
		in knots	in m/sec	
Calm	0	<1	0 - 0.2	-
Light air	1	1 - 3	0.5 - 1.5	0.1
Light breeze	2	4 - 6	1.6 - 3.3	0.2
Gentle breeze	3	7 - 10	3.4 - 5.4	0.6
Moderate breeze	4	11 - 16	5.5 - 7.9	1.0
Fresh breeze	5	17 - 21	8 - 10.7	2.0
Strong breeze	6	22 - 27	10.8 - 13.8	3.0
Near gale	7	28 - 33	13.9 - 17.1	4.0
Gale	8	34 - 40	17.2 - 20.7	5.5
Strong gale	9	41 - 47	20.8 - 24.4	7.0
Storm	10	48 - 55	24.5 - 28.4	9.0
Violent storm	11	56 - 63	28.5 - 32.6	11.5
Hurricane	12	64 - +	32.7 - +	>14

* This column is only a guide, showing roughly what may be expected in the open sea, far from land.

Table 3. Sea state

DESCRIPTIVE TERM	SEA STATE	WAVE HEIGHT
Calm (glassy)	0	0
Calm (rippled)	1	0 - 0.1
Smooth (wavelets)	2	0.1 - 0.5
Slight	3	0.5 - 1.25
Moderate	4	1.25 - 2.5
Rough	5	2.5 - 4
Very rough	6	4 - 6
High	7	6 - 9
Very high	8	9 - 14
Phenomenal	9	>14

The sea state is completed with SWELL indications:

Height		Length		Direction
Small	0 - 2 m	Short	0 - 100 m	If different of the wind
Moderate	2 - 4 m	Medium	100 - 200 m	
High	4 m	Long	200 m	

Table 4. Nebulosity

Part of the sky covered with clouds in oktas from 0 to 8

0: no clouds
8: entirely cloudy

Chapter 6

LIGHTERING VESSELS IN PERIL

1. GENERAL INFORMATION

Considering the difficulties and cost of oil pollution combating both at sea and on shore, it is necessary, whenever possible, to remove the potential pollutant from a vessel in peril if there is a threat of its spillage. This obviously concerns the cargo of tankers as well as fuel oil of all other types of vessels. This Chapter only deals with oils in grounded vessels, drifting vessels or vessels in great peril. The case of oils retained in sunken wrecks, which is beyond the scope of this Guide, presents generally a less urgent problem and should be the subject of a specific study.

The present 'state-of-the-art' in technology does not permit the quick transfer of oils which are not fluid enough. Most often the pumping rates are low despite the urgency of the operation.

2. ORGANIZATION OF OPERATIONS

All lightering operations involving a vessel in peril should be preceded by a rapid legal action. Practically it means that rights and responsibilities of ship owners, ship managers, crew and particularly the master, insurers and finally the State should be defined.

Once the decision to lighter the vessel has been taken, either the national means (equipment) can be used, if the country involved disposes of them, or the means of specialized (salvage) companies under the supervision of (national) maritime authorities. The contract should include the responsibilities of the State and of the contractor for the general safety of the operation and precise the terms of co- ordination of various actions.

3. ASSESSMENT OF THE SITUATION

- Every accident presents a hindrance to the navigation of other vessels. These should be warned immediately and instructed on safety measures (Notice to mariners). If necessary, the zone of accident should be marked by buoys.

- Proximity to shore and bases of personnel and materials will determine the promptness of the intervention. Meteorological conditions may delay the possibilities of action. Specialized lightering tankers are generally not operational if wind exceeds 25-30 knots and sea state exceeds Force 5 (wave heights up to 3 metres).

- If oil is already spilled on the sea, evaporation of hydro- carbons may create an explosion risk and prevent temporarily the access to the site. Measurements made during various past accidents suggest that a delay of 2 hours is sufficient for the light breeze to dilute the atmosphere below the explosion limit of 1%, obviously providing that the leakage has been stopped. Nevertheless, the risk of intoxication of personnel, which may persist, necessitates precautions and use of safety equipment during the access.

4. TYPES OF ACCIDENT

4.1 Collision

A classic accident which may result in a more or less serious pollution: for information only, the smallest wing cargo tank of a VLCC has a volume of about 10 000 m^3. The crash can also cause a rupture in the internal structure. Disposition of cargo is accordingly modified and an abnormal stress upon the hull may result. In order to prevent the hull rupture or to avoid foundering of a part of the vessel, immediate lightering of certain tanks can be envisaged. In accordance with the gravity of the problem and their own competence, the crew on board the tanker has to start internal cargo transfer and to indicate the possibilities of immediate lightering.

4.2 Fire/explosion

There is a danger that the above mentioned type of accident can result in an explosion or fire, thus increasing the risk of rupture of the ship and reducing the possibilities of the crew's intervention.

Unfortunately, collision is not the only cause of fire and explosion on board vessels. Besides the common risks of fire in accommodation quarters or engine room attended by a very limited number of personnel, a permanent risk of explosion, caused by the nature of cargo, exists on certain vessels. It is not possible to envisage any transfer of the cargo before the fire is extinguished. The risk of this type of accident is greater when the vessel is empty or during tank washing, gas freeing and ballasting operations. It may also be necessary to transfer the contents of fuel oil tanks, other (for example, lubricating) oil tanks and tanks for cargo residues.

4.3 Grounding:

The leakage of pollutant can be relatively small, at least during the first few hours, while the structure of the vessel is not affected. The crew can try to limit the consequences of the accident by taking, for example, one of the following actions:

- transferring the cargo, if it is liquid, from damaged to intact tanks, using normal piping in an attempt to refloat the vessel;
- jettisoning possibly a part of the cargo on the sea, if this may help to relieve the perilous situation of the vessel aggravated either by grounding during periods of high tide or by worsening of the sea state;
- depressurizing damaged tanks in order to reduce leakage of pollutant below the water-line.

The efficiency of assistance will mainly depend on:

- meteorological conditions;
- availability and proximity of lightering equipment, towing vessels and storage capacities.

5. SHIPS'S CAPABILITIES

The following check-list indicates information which should be known:

a) **<u>Situation of the ship:</u>**

afloat; damaged; aground.
empty; laden : (characteristics of cargo)
bunker : (quantity / nature)

b) **<u>Crew:</u>**

Evacuated; on board; qualifications; specializations.

c) **<u>Available means:</u>**

Propulsion engine/steam.
Steering gear.

Capstans, cable holders, windlasses, etc ...
Electric current supplies: main, auxiliary.
Steam supplies: main, auxiliary.
Pump room.
Fire fighting system.
Tanks' heating system.

d) **Stability:**

Length:
Breadth:
Displacement:
Void spaces:
List:
Trim:
Computer on board:
Computer on shore:

e) **Buoyancy:**

	Empty	Full	Quantity
Forward:			
Midships:			
Aft:			

6. MEANS

Responsible authorities should primarily call upon professional salvage companies. However, they can decide to take proper immediate action; since it may be impossible to obtain rapidly the assistance of professional salvage companies.

Authorities have to be promptly and exactly informed on the problem: experience proves that it is very difficult to obtain precise information from the ship, especially if a language problem exists.

Availability of emergency teams should be envisaged in the National Contingency Plan:

- evaluation team which will have to assess the gravity of the problem, to help the master of vessel in peril and to inform the authorities on shore;

- intervention team which will be made up of specialists and have at its disposal a minimum of equipment, preferably portable by helicopter, having at the same time, knowledge of specific safety measures for working on tankers.

The authorities should dispose of tug boats; they are indispensable for removal of vessel in peril, but they can as well be equipped for supplying distressed vessel with electric current, compressed air, steam, fresh water, etc ... They can be used for the quick transportation of lightering equipment and possibly floating tanks.

Major oil companies also have, as a part of their Contingency Plans, promptly available teams whose assistance can be particularly efficient.

6.1 Specialized lightering tankers

As far as a distressed tanker has her cargo pumping system energy supply operational, the use of specialized lightering tankers should be considered straight away, especially those which are equipped with an inert gas generator.

However, increasing tonnage of these vessels, (generally between 60>000 and 100 000 tons), their small number and their relative unavailability do not permit reliance upon their systematic use.

6.2 Coastal tankers

These vessels are interesting due to their manoeuvrability, their big number, their availability and their specific and non-negligible storage capacity.

To make them suitable for lightering, they should be equipped with fenders, flexible hoses, moorings, portable VHF radio-telephones, etc.

Maritime authorities should prepare preliminary arrangements with owners of coastal tankers for their use in cases of emergency.

6.3 Vessels other than tankers

These vessels can be used for lightering (for example, of solid products) or simply for transport of intervention equipment and also sometimes as storage facilities. The most interesting vessels for this kind of emergency intervention are basically tug boats, supply vessels and dredgers.

6.4 Helicopters

Because of their speed and convenience, helicopters should be used, whenever possible, for the transportation of intervention equipment. Dimensions and weight of this equipment are normally adapted to transportation by helicopters.

6.5 Specific equipment

- Hydraulic unit;
- Submersible pumps with tripod (gyn) or gantry for their deployment;
- Inert gas generator, heating unit, venting unit;
- Safety equipment: explosimeters, analysers, lifelines (indispensable);
- Fenders;
- Flexible hoses and couplings;
- Flexible tanks;
- Special tools for opening of hull;
- Measuring equipment and portable lighting equipment;
- Portable communications equipment;
- Anchoring and manoeuvering equipment.

7. CONDUCTING LIGHTERING OPERATIONS

Each lightering operation represents a particular case, taking into consideration environment, situation and condition of the vessel in peril, nature of the product which has to be transferred, techniques and usable means. Extreme variability of these parameters makes it impossible to set up general rules on how to conduct this type of operation. However, one imperative remains permanent and that is the saftey of personnel. Prevention of pollution does not justify taking an unreasonable risk for the personnel. It is even more important to stress this fact because the teams taking part in the operation may find themselves in certain hazardous situations to which they are not used to, for example, toxic atmosphere or unfamiliar environs. A checklist used for **commercial lightering operations**, that is reproduced on the following pages is given only as an example and **should be modified** for each particular case of emergency operation.

CHECK-LIST FOR COMMERCIAL LIGHTERING OPERATIONS

SHIP: ________________________ DATE: __________________

QUAY NO.: _____________________ TIME: ______________________ YES NO

1. Is the ship securely moored?
2. Are the fire protection tow lines correctly installed?
3. Does the access from ship to shore conform to the safety regulations?
4 Is the ship ready to manoeuvre under her own power?
5. Is a continuous and effective watch being kept on deck and a supervision adapted to the terminal?
6. Are the communications between the ship and the shore operational?
7. Has the procedure for handling loading, bunkering and ballasting been approved?
8. Has the procedure for the emergency stopping of operations been approved?
9. Are the fire-hoses and fire-fighting equipment on board and on shore ready for immediate use?
10. Are the loading and bunkering lines and/or arms in good condition and properly rigged?
11. Are the scuppers properly plugged and the drip pans properly installed on board and ashore?
12. Are the unused lines, including the stern line, if it exists, properly plugged?
13. Have blank flanges been fitted on the unused deck and bilge lines?
14. Have the sea valves and unused deck valves been closed and secured?
15. Are all covers of loading and bunkering tanks closed?
16. Is the system of evacuation of gas from the tanks of an approved type?
17. Are the flash-lamps of an approved type?
18. Are the VHF walkie-talkie sets of an approved type?
19. Are the ship's main transmitting aerials insulated?

20. Are the electric cables supplying portable equipment disconnected from their power supply?

21. Are all doors and portholes of the midship accommodations closed?

22. Are all doors and portholes in the aft-accommodations opening onto the tank deck closed?

23. Are all air-conditioning vents in areas exposed to gas closed?

24. Are all window-type air conditioning units disconnected?

25. Are the regulations concerning smoking being applied and observed?

26. Are the regulations concerning the use of the galley being applied and observed?

27. Are the regulations concerning the use of naked flames being applied and observed?

28. Are the ventilator cowls (if the ship is fitted with them) correctly directed in relation to the prevailing wind?

29. Are tours of inspection of the pump room carried out at the start of operations and every two hours thereafter?

Remarks: The undersigned have checked together all the items on the above list and have personally made sure that, to the best of our knowledge and belief, the check-marks shown on the list, are justified and correct.

CHECKED BY: ______________________________ (Name - Rank)
(Ship's Officer)

____
Countersigned by Port Officer:

Chapter 7

CONTAINMENT OF OIL AND THE USE OF BOOMS

1. INTRODUCTION

When spilled on the sea (water) surface, oil will not remain confined to the place of spillage. Gravity will cause its spreading and winds and currents will result in its displacement. Both these actions will have adverse effects on any attempt made to remove spilled oil from the sea surface, which is the final aim of all spill control activities.

Any obstruction in the course of the oil will normally influence its motion, but only coastline will definitely terminate this process. Since in most cases the uncontrolled arrival of oil on a coastline is the least desirable result of an oil spill, achieving a certain control upon oil movement and spreading has been one of the prime goals of oil spill control technology.

Some results in terms of oil spill containment can be attained using improvised barriers such as logs, sleepers (rail-road ties), beams, poles, air inflated fire hoses, earth or sand dams, etc. However, only purposely-built floating barriers (usually called floating booms or only **booms**) are capable of providing a reasonably high degree of spilled oil movement control.

2. DEFINITION

Booms can be defined as devices (floating barriers) specially designed for the control of oil movement on the sea (water) surface, by containing, concentrating or directing spilled oil.

The main objectives of using booms are:

- to concentrate spilled oil in order to facilitate its recovery;
- to protect certain parts of a coastline from contamination with spilled or refloated oil.

However it is important to understand that there is no such boom that can retain the oil for an indefinite period of time and that the oil concentrated by it needs to be removed, using some kind of recovery device, as quickly as possible. If the oil is not successively removed from the contact with the boom, it will inevitably, sooner or later, start escaping from where it has been confined by the boom.

3. DESIGN

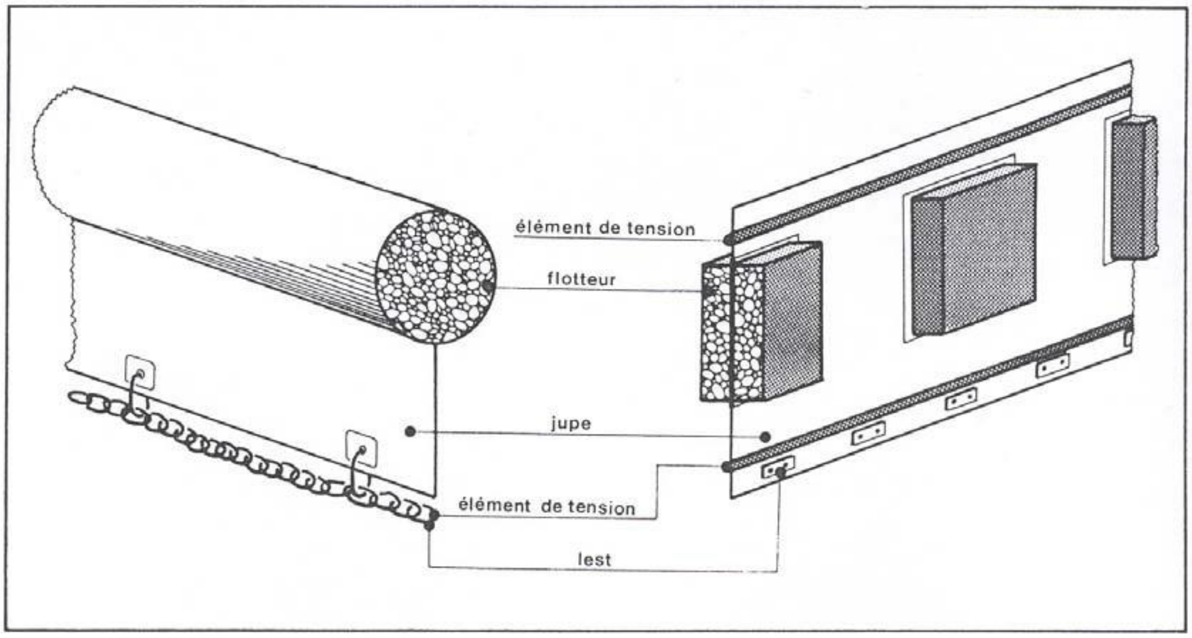
3.1 Construction elements

Commercialized booms are available in various shapes and sizes, however, regardless of their design, five basic elements can be distinguished in each of them:

- Floatation element / float.
- Oil retention element / skirt.
- Ballast.
- Tension member.
- Connectors / couplings.

Properly designed booms will also have anchor points built in or attached to the boom structure.

Figure 1. Basic boom construction elements



Flotation element (float) provides for the buoyancy of the whole system (boom), but often functions as an additional freeboard to reduce splash-over. It can be filled either with some solid material (expanded plastic foams e.g. polyethylene, polyurethane, polystyrene or natural flotation materials e.g. cork, wood, etc ...) or with air.

Skirt acts as a barrier which prevents spreading of oil underneath the water surface. Skirt's depth affects the efficiency of the boom, but also influences a great deal the total load exerted on the whole system. Skirts of most booms are made in synthetic rubber or other plastic-coated fabrics, but non-reinforced plastic materials, nets or metal sheets have also been used in certain designs.

Ballast is attached to the bottom of the skirt to keep the boom in position perpendicular to the water surface. In most cases it is either chain (special or galvanized steel, lead) or specially designed metal weights (lead, galvanized steel). In a particular design water-filled tube acts as skirt and ballast at the same time.

The function of a **longitudinal tension member** is to provide the whole system with enough tensile strength, bearing most of the load created by winds, waves and currents. It can either be incorporated in the boom (nylon rope, webbing, wire cable) or attached to the boom as a separate tension member (stainless steel cable, rope). In some designs the ballast chain also acts as a tension member. If the material out of which the whole boom is made has sufficient tensile strength for envisaged working conditions (sea state, winds, currents), no additional longitudinal tension members are added.

Since booms are produced in sections of standard lengths, it is usually necessary to connect several such sections in order to obtain the adequate length of boom for a specific purpose. Therefore, to enable connecting several sections of boom **connectors** (or couplings) are attached on both ends of each section. Again, different designs are used by different manufacturers, although there is a type known as "universal" connector that has been proposed in order to facilitate coupling, if necessary, booms of different designs.

3.2 Types of booms

Booms can be classified in two categories as regards their basic design:

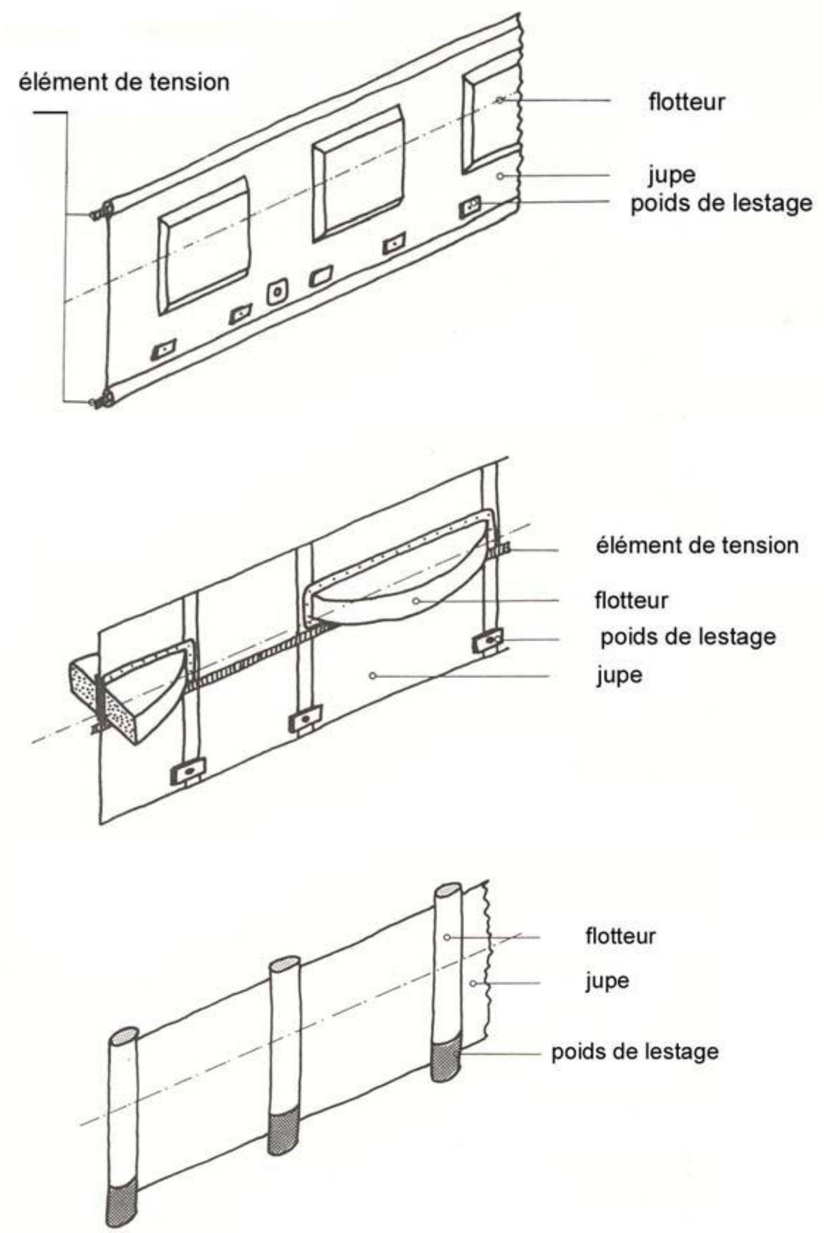
- Fence booms.
- Curtain booms.

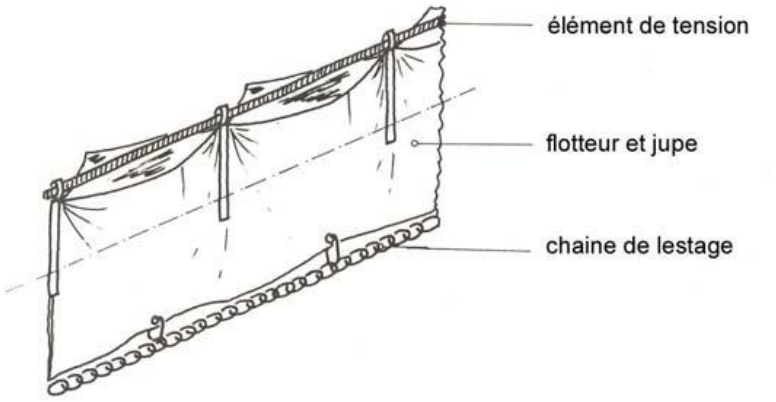
3.2.1 Fence Booms

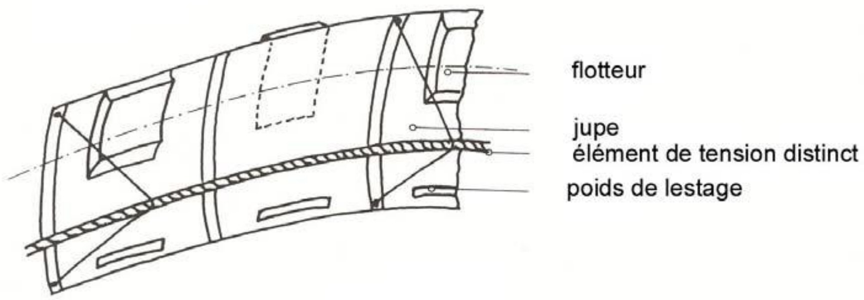
Fence booms have a vertical screen extending above and below the water surface thus acting at the same time both as freeboard and skirt. A flotation element is either bonded to the "fence" or integrated in it to provide for the buoyancy of the boom. Their cross section is usually (but not always) more flat than that of curtain type booms. Fence booms are kept in position perpendicular to the water surface by weights (ballast) attached to the bottom of the screen.

Typical fence boom designs are illustrated in **Figure 2**.

Figure 2. Fence boom designs





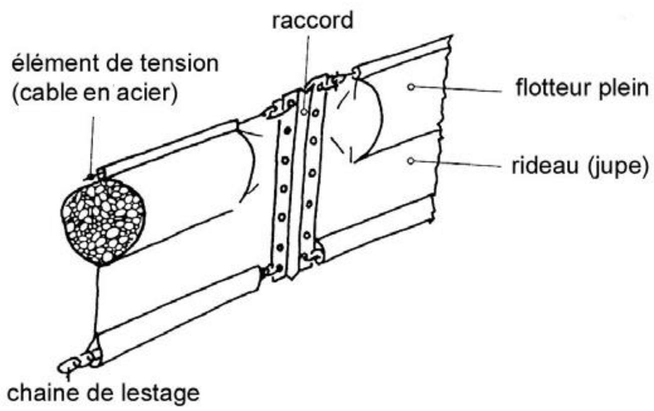


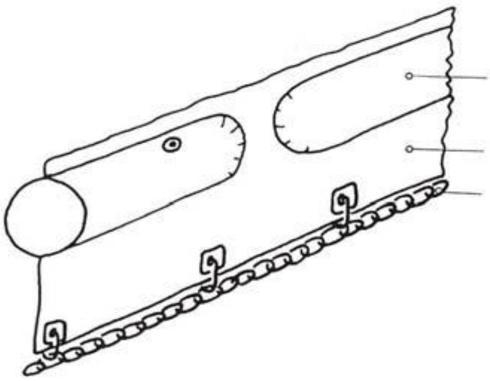
3.2.2 Curtain booms

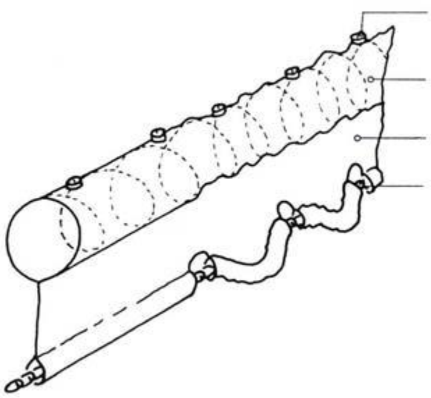
Curtain booms have a longitudinal flotation element, acting as a freeboard, with subsurface curtain (skirt) suspended from it. Ballast is normally attached to the base of the skirt to keep it in a vertical position. The tension member can either be integrated (built in) in the boom or attached to it. In some designs ballast chain also acts as a tension member.

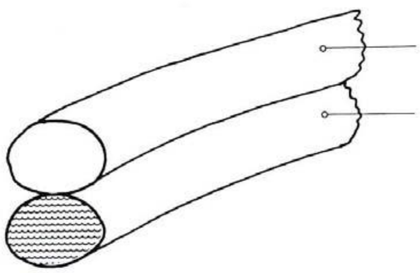
Characteristic designs of curtain booms designs are illustrated in **Figure 3**.

Figure 3. Curtain booms designs









3.3 Boom material behaviour

Material of which a boom (of either fence or curtain type) is made will largely determine the way in which it behaves on the sea surface. Classified by their behaviour, booms can be:

- Flexible.
- Semi-flexible.
- Rigid.

Flexible booms will not resist (or will resist only slightly) to changing their shape in accordance with the water surface motion.

Semi-flexible booms will follow the shape of water surface with some resistance.

Rigid booms will keep their original shape regardless of the waves and water agitation.

Most commercial booms fall under the second category (semi-flexible booms), which actually represents a compromise between necessary elasticity of the boom assembly and its required strength.

3.4 Dimensions

The size of commercially available booms varies considerably. The overall width may range between 0.3m to 3m. In most designs the draft accounts for approximately 60% of the overall width and the freeboard for the other 40%.

In most cases, commonly used booms have the width ranging between 0.5m and 1.5m.

Booms are usually manufactured in sections, the length of which varies between 5 to 500m. These can be joined together by means of connectors (couplings) attached to both ends of a section.

4. USE OF BOOMS

According to the function booming may be classified as:

- containment booming
- protection booming (including deflection booming)
- collection booming (trawling)

4.1 Containment

Booms are deployed in such a way as to prevent spreading of oil over the water surface, that is, to localize the effects of spilled oil (near its source). It is absolutely necessary to remove confined oil successively because the boom will be able to prevent its movement and escape from the enclosed area for only a limited period of time. Provided that limiting factors (see para 5.1) permit this mode of application it can be used for:

- Localizing spilled oil near its source (Figures 4 and 5).

Figure 4

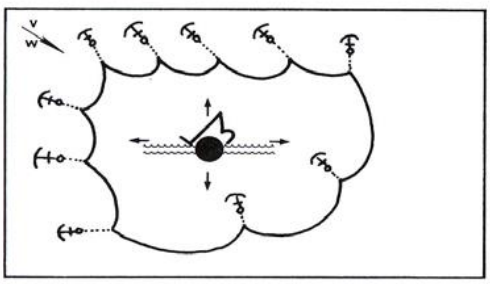
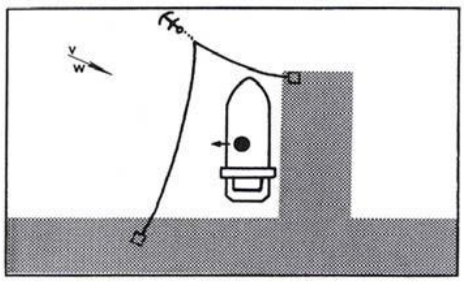


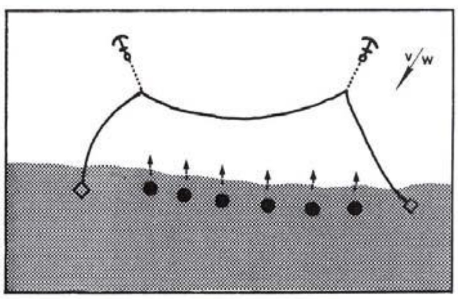
Figure 5

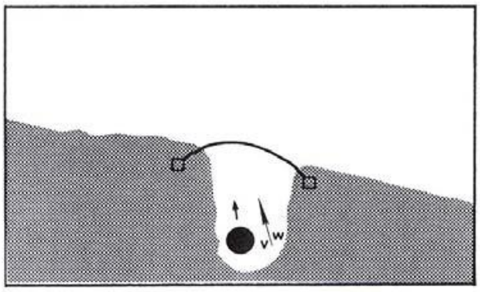


- Preventing recontamination of the shoreline by oil either trapped on beaches, in small bays and coves, tidal pools, etc... or washed off during clean-up operations (Figures 6 and 7).

Figure 6

Figure 7





4.2 Protection

When a specifically sensitive area (environmentally or economically) has to be protected from oil contamination, protective (or exclusion) booming is applied. Again it is necessary to combine booming and oil recovery if the chosen site is to be effectively protected (Figures 8 to 11).

Figure 8

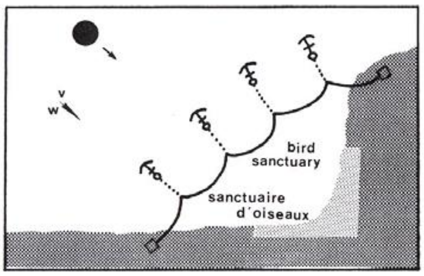


Figure 9

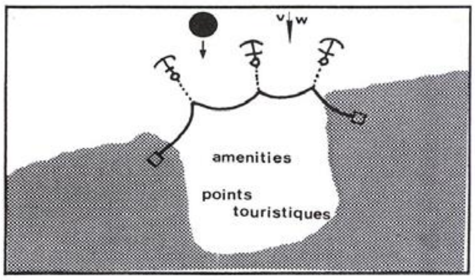


Figure 10

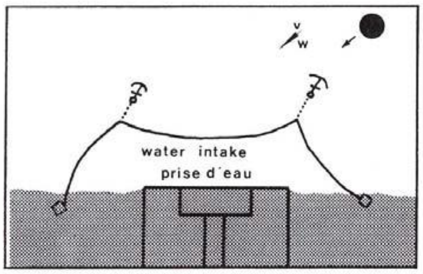
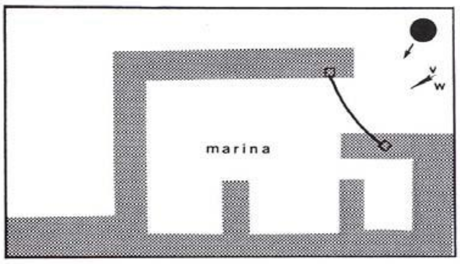


Figure 11



Deflection booming, also called "diversion" booming, can be considered as a specific type of protection of coastal resources. It is applied when it is desirable to divert spreading oil from a sensitive area (bay, cove, harbour entrance, yacht marina, beach, etc...) to a place which is less sensitive and more suitable (currents, land configuration) for the collection (removal, recovery) of oil. To make the most of this method, which is illustrated in Figures 12 to 15, the boom should be deployed at an angle to the direction of incoming oil (see paragraph 5.1).

Figure 12

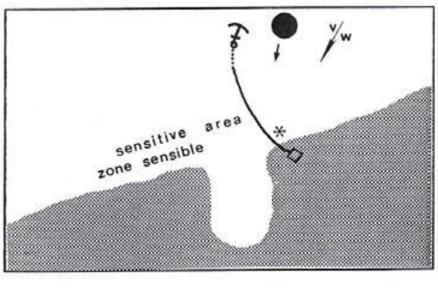


Figure 13

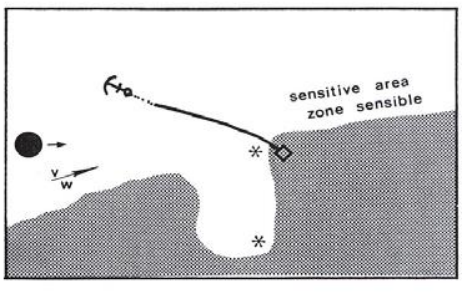


Figure 14

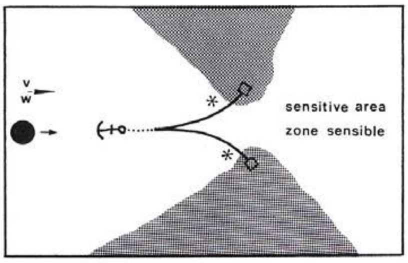
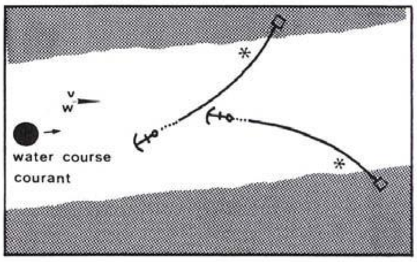


Figure 15

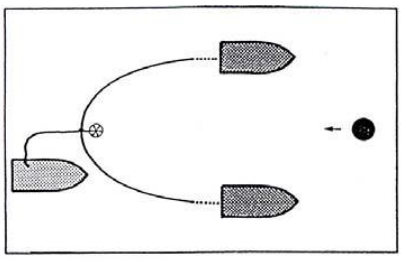


4.3 Collection

Collection booming, also called trawling, is used for concentrating oil floating on the sea surface in order to facilitate its removal (recovery) and minimize its spreading. To use a boom for oil collection, a system consisting of one, two or three vessels and a boom has to be deployed. Selection of suitable vessels is critical, since very few are able to maintain necessary navigational properties at extremely low speeds required for effective collection booming. Problems associated with the coordination of multi-vessel systems further limit the applicability of this spill response method. It is completely useless and ineffective if the rate of oil removal does not correspond to the rate of oil collection.

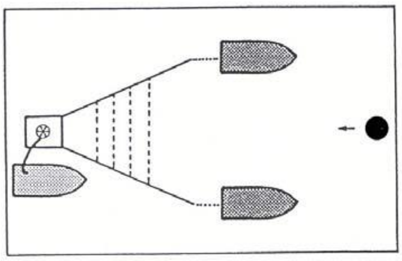
Different configurations of trawling systems that can be applied are illustrated in **Figures 16 to 19**.

Figure 16



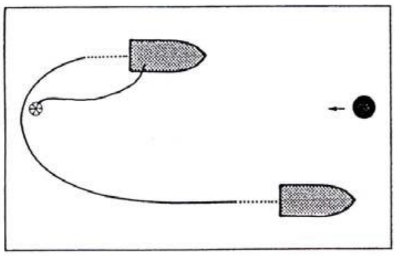
U - configuration: boom towed by two vessels and recovery unit deployed from a third one.

Figure 17



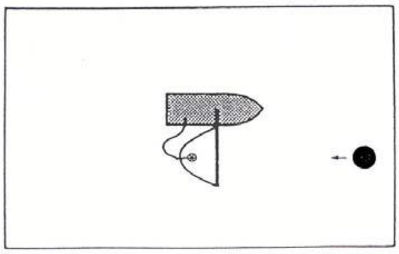
V - configuration: boom and recovery unit towed by two vessels - oil transferred to the third vessel.

Figure 18



J - configuration: boom towed by two vessels and recovery unit deployed from one of them.

Figure 19



Single vessel system: boom and recovery device deployed from one vessel, generally with the help of a jib.

From all that has been said above, it is obvious that there are two different ways (modes) in which booms can be used:

- Stationary (mooring - moored booms).
- Mobile (towing - towed booms).

Booms will be used in stationary mode (moored) for containment and protection booming, while towed booms (in mobile mode) will be used for collection booming.

The way in which a boom will be used and (in certain cases) which type of boom will be selected depends on a number of factors including:

- location and size of oil spill;
- meteorological conditions;
- oceanographic conditions;
- movement of the slick;
- land form and water body configuration;
- sensitivity of the area and priorities for protection.

5. GUIDELINES FOR THE USE OF BOOMS

Although for an inexperienced person, a boom may look like a universal and definite response to an oil spill, this impression is mainly wrong. Use of booms is limited by numerous factors and if these limitations are not observed, they will render any boom a completely ineffective and useless tool. Most of the limitations are of purely physical nature and possible further improvements in boom design are not likely to radically change the situation. Notwithstanding the theoretical work on boom design and application that has been done so far, most of the guidelines given further on in the text are results of experiments and experience gained through (very often erroneous) use of booms. It should always be kept in mind that boom deployment is in most cases a hard and labour-intensive job, which frequently results in a failure. Probably the best piece of advice that can be given is to analyze each such failure, identify mistakes that have been made and try to avoid and to correct them in the future.

It should be borne in mind that booms could be used effectively only if careful preplanning for their deployment, use and retrieval has been done. In addition, personnel designated to handle booms in case of an emergency has to be regularly trained (when there are no emergencies).

5.1 Oil Retention Capability

Winds, waves and currents largely affect the performance of a boom. Under their influence oil contained by a boom will tend to continue its movement that has been interrupted by boom deployment across its course. Oil can escape either over the boom's freeboard (splash-over) or underneath its skirt (underflow). Winds and waves generally cause splash-over and currents are responsible for underflow of oil. Both phenomena affect both moored and towed booms.

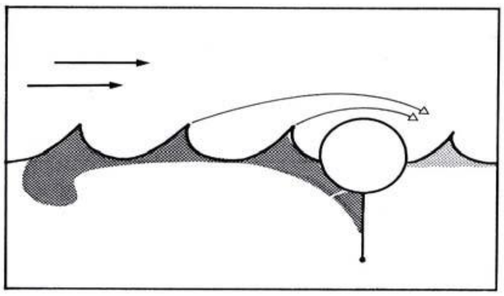
5.1.1 Splash-over

Long waves (length to height ratio $\geq$ 8) should not influence the boom's performance if the boom is flexible enough, however short period waves (length to height ratio $\leq$ 4 and smaller) may cause splash-over. These waves are normally generated in restricted areas.

The only way to overcome the problem of splash-over is to increase the size of a boom (freeboard), that is, to use a larger boom(s) if choppy conditions are expected in a certain area. It should be kept in mind that deployment of a larger boom requires more time, personnel and additional equipment.

Figures (very often exaggerated) given by manufacturers on boom performance in waves and winds correspond more to the limits of a boom's resistance and integrity rather than to its capacity to retain oil.

Figure 20 Splash-over



5.1.2 Underflow

Figure 21 Entrainment of oil

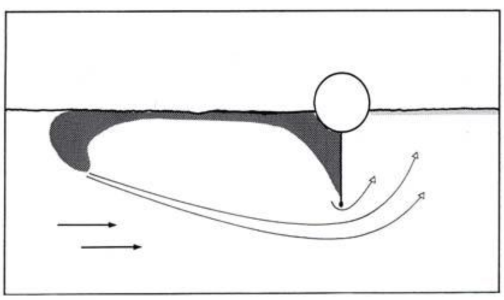
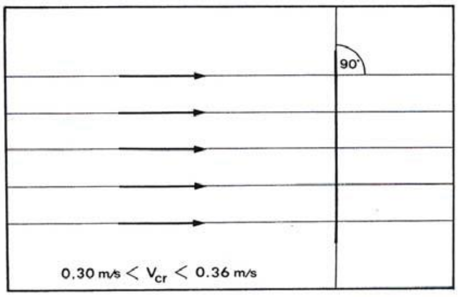


Figure 22 Critical velocities



It was discovered that if the current velocity at right angles to a boom's section exceeds a certain value, oil starts escaping underneath the boom. For most of the booms this "critical velocity" is between 0.58 and 0.70 knots (0.30 and 0.36 m/s).

This phenomenon known as "entrainment" cannot be avoided by increasing the depth of the skirt. Oil droplets that will be swept under the boom are particles of "head wave" which is formed upstream of the boom and of the oil mass formed immediately in front of the boom. "Dragging" effect created by the current will not sweep these droplets under the skirt only if collected oil is successively and continuously removed from boomed area.

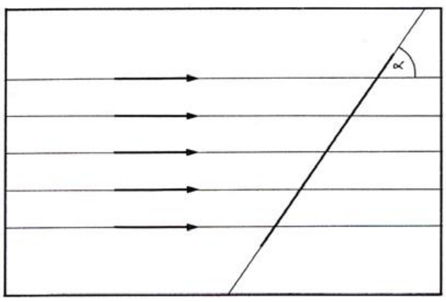
It was also noted that the performance of a boom in currents exceeding the "critical velocity" can be improved by positioning the boom at an acute angle to the flow. Relative current velocity will thus be reduced and oil will be retained by the boom and diverted alongside it to a place where it can be recovered more easily.

The angle between a section of boom and the current direction should satisfy the following inequality if "entrainment" is to be avoided:

$$\sin \alpha \leq \frac{V_{cr}}{V_{cu}}$$

V_{cr} = Critical velocity
V_{cu} = Velocity of current
V_{cr} and V_{cu} should be expressed in the same unit (knots or m/s)
α = Acute angle between a boom section and current direction

Figure 23 Boom positioned at an acute angle to the flow



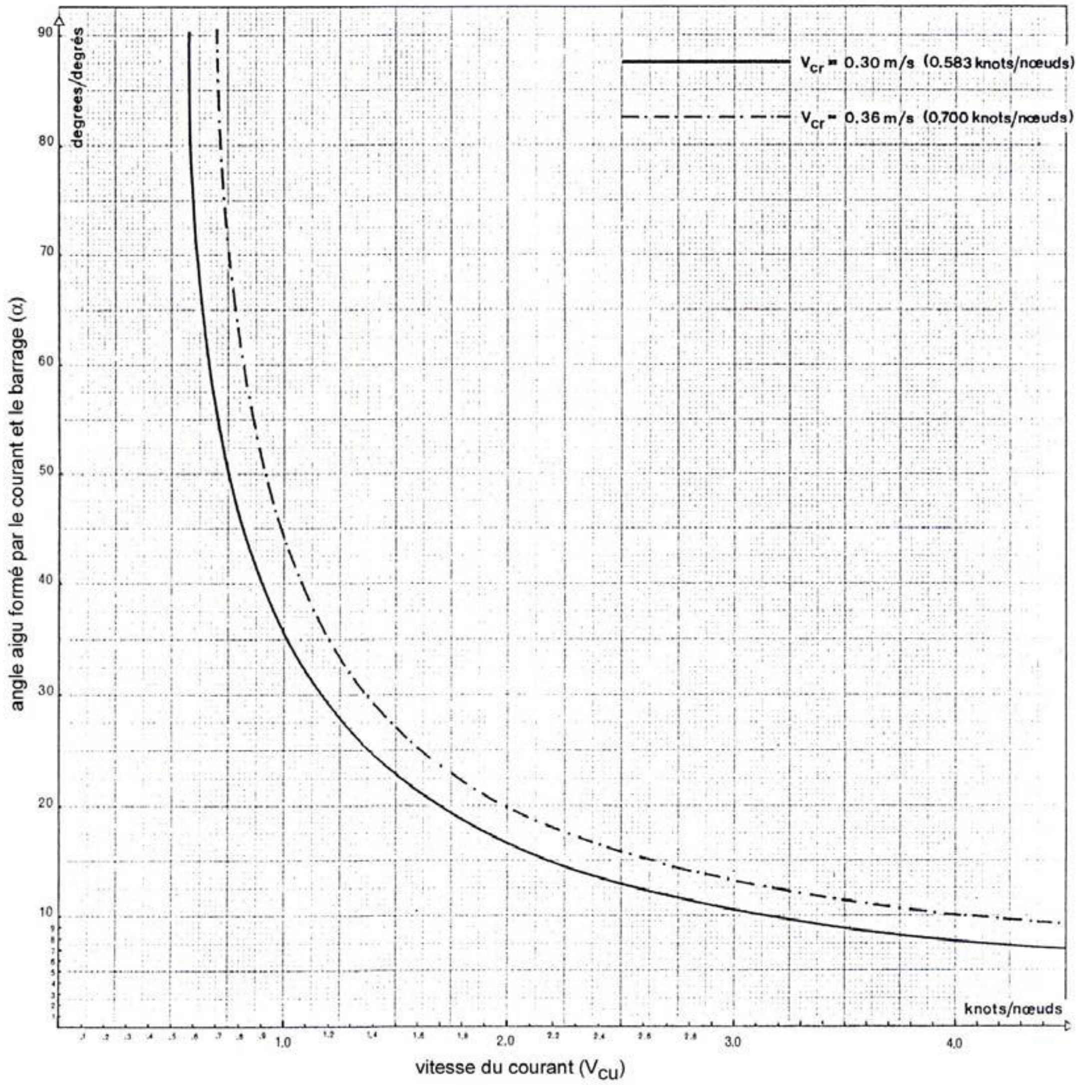
Tables 1 and 2 and diagram in **Figure 24** give respective angles for both afore mentioned critical velocities (0.30 m/s and 0.36 m/s) and current velocities between critical velocity and 5 knots. For any critical velocity other than these two, corresponding angles can easily be calculated.

Critical Velocity 0,36 m/s (0.583 knots)			
V current		sin a	Angle Degrees
Knots	m/s		
0,583	0,30	1,000	90
0,6	0,31	0,968	75
0,7	0,36	0,833	56
0,8	0,41	0,732	47
0,9	0,46	0,652	41
1,0	0,51	0,588	36
1,1	0,57	0,526	32
1,2	0,62	0,484	29
1,3	0,67	0,448	27
1,4	0,72	0,417	25
1,5	0,77	0,390	23
1,6	0,82	0,366	21
1,7	0,88	0,341	20
1,8	0,93	0,323	19
1,9	0,98	0,306	18
2,0	1,03	0,291	17
2,1	1,08	0,278	16
2,2	1,13	0,265	15
2,3	1,18	0,254	15
2,4	1,23	0,244	14
2,5	1,29	0,233	13
2,6	1,34	0,224	13
2,7	1,39	0,216	12
2,8	1,44	0,208	12
2,9	1,49	0,201	12
3,0	1,54	0,195	11
3,5	1,80	0,167	10
4,0	2,06	0,146	8
4,5	2,32	0,129	7
5,0	2,57	0,117	7

Critical Velocity 0,36 m/s (0.7 knots)			
V current		sin a	Angle Degrees
Knots	m/s		
0,7	0,36	1,000	90
0,8	0,41	0,,878	61
0,9	0,46	0,783	52
1,0	0,51	0,706	45
1,1	0,57	0,632	39
1,2	0,62	0,581	35
1,3	0,67	0,537	33
1,4	0,72	0,500	30
1,5	0,77	0,468	28
1,6	0,82	0,439	26
1,7	0,88	0,409	24
1,8	0,93	0,387	23
1,9	0,98	0,367	22
2,0	1,03	0,350	20
2,1	1,08	0,333	19
2,2	1,13	0,319	19
2,3	1,18	0,305	18
2,4	1,23	0,293	17
2,5	1,29	0,279	16
2,6	1,34	0,269	16
2,7	1,39	0,259	15
2,8	1,44	0,250	14
2,9	1,49	0,242	14
3,0	1,54	0,234	13
3,5	1,80	0,200	12
4,0	2,06	0,175	10
4,5	2,32	0,155	9
5,0	2,57	0,140	8

Figure 24 Critical velocity (V_{cr}) as a function of current velocity (V_{cu}) and acute angle between the current and the boom (α):

$$V_{cr} = V_{cu} \times \sin \alpha$$



Current Velocity (V_{cu})

Acute angle between the current and the boom (α)

In very shallow waters critical velocities are less than normal (0.6 to 0.7 knots) and accordingly given values for angles corresponding to certain current velocities will not apply. Given figures are applicable only if water depth is 5 times the boom's draught or more.

Lastly it has to be emphasized that "entrainment" of confined oil will occur whenever there is a relative speed of the boom in relation to the water surface. Accordingly, a boom moored in the current and a boom towed by two vessels will be affected in the same way.

5.2 Moored Booms

To provide for an oil slick containment and deflection, as well as for coastline protection, it may be possible to use booms in a stationary mode, that is, moored.

The number of mooring points, the type of mooring gear, weight of anchors etc ..., will depend on forces which the mooring points are supposed to sustain. These forces will mainly depend on currents, winds and waves in the area where the boom is deployed and on the size of the boom used. It is not possible to calculate their accurate values (because they depend on too many factors) but an approximate value of forces exerted on a boom can be evaluated. Formulae suggested below will give more correct values for a rigid barrier than for a flexible boom, but values obtained when using them will certainly provide useful information for dimensioning anchors and predicting naval means for handling same.

The total force exerted on a certain boom length will be a combination of forces exerted by current and wind separately. The force exerted by a current will be:

$$F_c = K \times A_s \times V_c^2 \qquad (1)$$

F_c = Force exerted by current [kg]
K = Proportionality constant
A_s = Subsurface area of a boom [m]
V_c = Current velocity [knots]

For proportionality constant value of 26 (K = 26) results of calculations will give an approximate value of, F_c which fairly corresponds to its actual value. For certain booms K may be less than 26, but it is more opportune to calculate with higher rather than with lower values.

Similarly, on the same boom, wind will exert force:

$$F_w = K \times A_f \times (V_w / 40)^2 \qquad (2)$$

F_w = Force exerted by wind [kg]
K = Proportionality constant
A_f = Freeboard area of a boom [m^2]
V_w = Wind velocity [knots]

It has been discovered that current of a certain velocity and wind of approximately 40 times greater velocity create equal pressure, and this is why V_w is divided by 40 in formula (2). Proportionality constant is the same as in formula (1): K = 26.

If both current and wind are acting in the same direction (the worst case) their combined forces will be:

$$F = F_c + F_w \qquad (3)$$

Example:

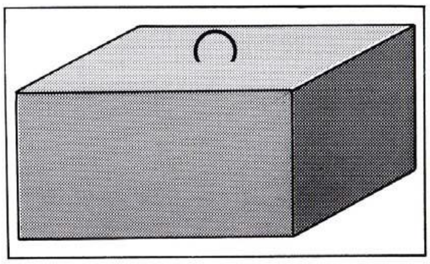
Boom length:	100 m
Freeboard:	0.6 m
Boom draught:	1.0 m
Current velocity:	0.4 knots
Wind velocity:	20.0 knots (same direction as current velocity)

(1) $F_c = 26 \times (100 \times 1) \times (0.4)^2 = 416$ kg
(2) $F_w = 26 \times (100 \times 0.6) \times (20/40)^2 = 390$ kg
(3) $F = 416 + 390 = 806$ kg

Since more or less permanent position of a boom and correct angle of its deployment has to be maintained (cf. paragraph 5.1) if anticipated boom effectiveness is expected, correct mooring becomes essential. Either anchors or concrete blocks can be used to achieve this.

Recommended anchors include the "Danforth" type (for sand, gravel, mud and clay) or the fisherman's type hook anchors (for rocky bottoms). For predetermined locations (particularly vulnerable areas, tanker terminals, cooling water intakes etc ...) concrete blocks can be permanently positioned (before an oil spill occurs).

Figure 25 Concrete block



The weight of a concrete block should be at least three times more than the expected load.

Figure 26 Fisherman's type anchor

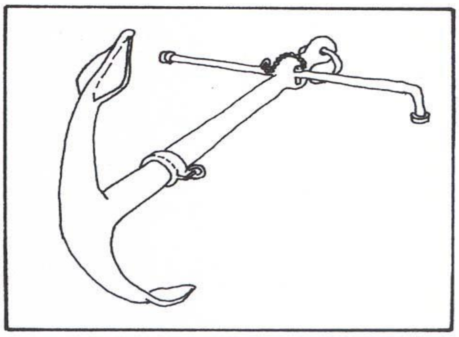


Figure 27 "Danforth" type anchor

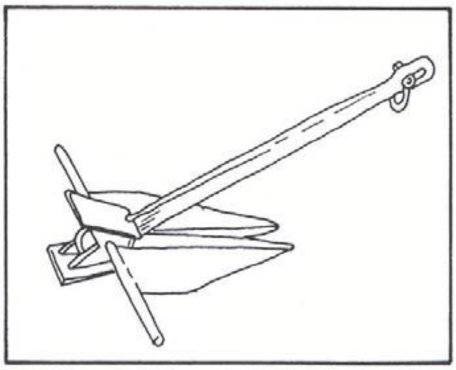
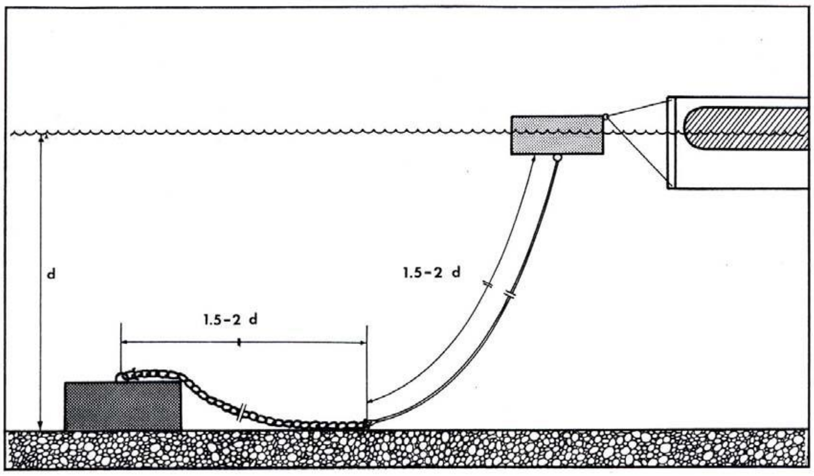


Table 3. Holding powers on different sea-beds of "Danforth" type anchors

ANCHOR WEIGHT [kg]	*HOLDING POWER [kg]*		
	MUD	*SAND or GRAVEL*	*CLAY*
15	200	250	300
25	350	400	500
35	600	700	700

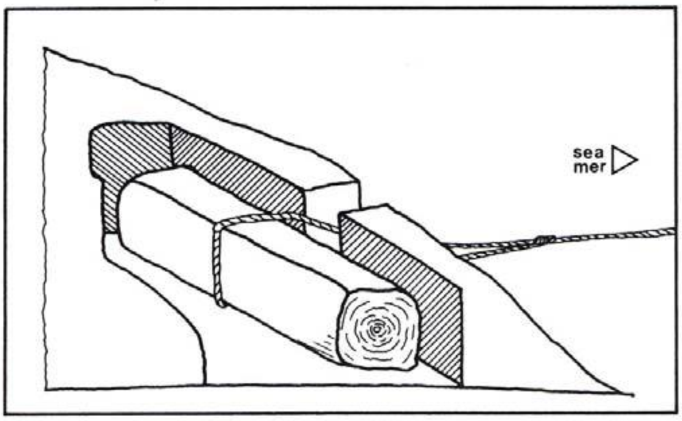
To compensate for wave movement, swell and tides, it is very important to have a proper length of mooring lines. As a rule of thumb a mooring line should be 3 to 4 times the depth of water at high tide. A section of heavy chain should be attached between the anchor (concrete block) and the mooring line in order to improve the holding power of the anchor. Also the boom should first be attached to a buoy and the buoy to a mooring line if submersion of the boom end is to be avoided. A typical mooring arrangement is illustrated overleaf:

Figure 28 Typical mooring arrangement



If an end of the boom (or both) is to be anchored to a shoreline, it can either be attached to an existing object (large tree or man-made structure) or an anchor system should be constructed. Very good results are obtained by so called "deadman". It is a log or beam buried in the hole in the direction perpendicular to the maximum pulling force expected:

Figure 29 "Deadman"



If the boom is anchored to a shoreline, a certain length of boom has to lie on the ground. The shore formation on the site selected for shoreline mooring has to be smooth (sand, gravel) as otherwise the boom damage will result during deployment on rough surfaces (boulders, rocks). The situation may be improved by using bags filled with sand as an "artificial" surface for boom deployment.

If it is likely that the boom will have to be attached to some kind of a man-made structure (e.g. a pier) a water tight mooring system can be prepared in advance (harbours, yacht marinas, tanker terminals).

In any case, it is essential to inspect anchoring points regularly and frequently and to adjust mooring arrangements if the need arises in order to give the most effective shape to the boom.

5.3 Towed Booms

Collection of oil in open seas is sometimes possible by using booms in mobile mode, that is, towed booms. This operation is more often than not restricted by adverse meteorological conditions or sea state. On the other hand (if conditions permit) it can be a very efficient way of eliminating the risk which an oil spill presents to coastal resources.

All estimates regarding escaping velocities of oil and forces exerted on a boom (paragraphs 5.1 and 5.2) apply to towed boom systems too, only the most relevant factor will now be towing speed rather than current velocity.

Any offshore boom with sufficient tensile strength may be used for oil sweeping, but better results can be expected from booms with separate tension member.

The successful outcome of a boom towing operation will greatly depend on the selection of towing vessels: these should have sufficient power and maintain their manoeuvrability under very low speeds (0.5 to 1.0 knots). It is assessed that 1 HP of an inboard engine is equivalent to 20 kg of pulling force. If two vessels are used, each should have approximately half of the required power. Twin propulsion vessels with variable pitch propellers and bow and stern thrusters are more likely to have necessary manoeuvrability than single propeller vessels.

Towing lines must be sufficiently long to compensate for sudden stresses. Their lengths should be at least 50 metres.

Since oil will escape from a U - formation boom more easily than from a V - shaped system, it is recommendable to connect two sides of boom with thin wire bridles at regular intervals (see Figure 17) in order to maintain a V - formation.

Oil will not escape from a towed boom only if relative towing speed (relative velocity between towed boom and the opposing current) is less than critical velocity (0.5 to 0.7 knots), and if oil is removed from the collection point (at the apex of used formation) at the rate corresponding to the collection rate.

Relative velocity of the whole system in the very strong current can be maintained below the critical velocity by letting the towing vessels drift sternwards.

Particular attention has to be paid to communications among vessels, because weak coordination may result in failure of the whole operation and, even worse, damage of equipment (booms) used.

6. SELECTION OF BOOMS

When considering the selection of a proper boom for a certain purpose, a potential buyer or user should firstly define his/her requirements. Therefore, a prospective boom user should know which parameters will determine the performance of a boom, as well as the approximate magnitude of these parameters for a certain envisaged location or use. It is only when these parameters have been defined that a serious selection of boom can be considered. Catalogues and manufacturers' technical papers are indispensable, but in addition, the experience of past users may also prove to be extremely useful. Demonstrations of equipment at sea (the worse the conditions the better) should also facilitate taking a decision.

The average values of main characteristics based on specifications of booms available on the market, are given in **Table 1**. It should be noted that given values refer to the type of equipment likely to be used in the Mediterranean. Accordingly, the figures do not refer to certain extremely small or extremely large booms that may also be available. The list of criteria for boom's selection is given in **Table 2** and may help in defining the requirements.

Table 4 Average characteristics of booms

Overall Width Hauteur totals		[m]	0.30 - 2.5
Free board Tirant d'air		[m]	0.10 - 0.70
Draft Tirant d'eau		[m]	0.15 - 2.00
Weight (with ballast) Poids (avec lest)		[kg/m]	1.50 – 25
Section length Longueur d 'un élément		[m]	5 – 200
Tensile strength *	Fabric (tear) Toile (au déchirement)	[kg]	50 – 600
Résistance à la traction *	Tension member Elément de tension	[kg]	1200 – 25000
Currents	Efficiency Efficacité	[knots] [noeds]	0.5 - 1.5
Courants	Physical damage Dommages physiques	[knots] [noeuds]	4.0 - 6.0
Winds	Efficiency Efficacité	[knots] [noeds]	< 20
Vents	Physical damage Dommages physiques	[knots] [noeuds]	20 - 40
Waves (depends on wave length)	Efficiency Efficacité	[m]	0.3 - 1.5
Vagues (dépend de la longueur des vagues)	Physical damage Dommages physiques	[m]	2.0 - 3.0
Température		[ºC]	-40 to/à +60

* Figures may significantly due to different testing procedures.
Chiffres pouvant varier considérablement en fonction des diffréntes méthodes de test.

Table 5. Criteria for selection of booms

1. OIL RETENTION CRITERIA

- Ability to follow the movement of sea surface
- Ability to prevent escape of oil underneath the skirt
- Ability to prevent splash –over

2. RELIABILITY CRITERIA

- Resistance to environmental conditions (sea, wind…)
- Tensile strength
- Length of flotation element

3. STORAGE AND UTILISATION CRITERIA

- Dimensions (overall width, freeboard, draft, section length)
- Weight
- Storage volume
- Transportation requirements
- Operational requirements: personnel, logistic support (e.g. air compressor, ...)
- Simplicity of: handling
deployment
connecting
retrieval

4. MAINTENANCE AND COST CRITERIA

- Resistance to: chemical action of oils
UV radiation
temperature
abrasion
floating debris
- Easiness of maintenance and cleaning
- Long shelf life
- Price and delivery times

Chapter 8

OIL RECOVERY AND RECOVERY DEVICES

1. INTRODUCTION

Elimination of oil from the sea (water) body on which it has been spilled is the main purpose of oil spill response activities.

Physical removal of oil is generally considered as having certain advantages over chemical removal, for example, no additional substances are introduced into the marine environment, less oil is irreversibly lost and recovered oil can normally be reused.

The following two basically different approaches can be distinguished in physical removal of oil:

- using non specific means, manual (buckets, shovels, etc ...) or mechanical (pumps, vacuum trucks, etc ...).
- using purposely built equipment.

This Chapter deals with means of physical removal of oil from the sea surface, and more specifically, it is restricted to discussing equipment and techniques specifically designed for oil recovery.

2. DEFINITION

The common name used for various oil recovery units is "oil skimmer" or simply "skimmer". Oil skimmer is defined as any mechanical device specifically designed for the removal of oil (or oil/water mixture) from the water (sea) surface without altering considerably its physical and/or chemical characteristics.

This definition comprises numerous designs and working principles utilised in skimmers' construction.

In most spill situations skimmers are used together with booms, but it is also possible to use them independently. It can be said that removal of oil, although closely linked, is not conditioned by the use of booms, in distinction from oil containment (by booms) which is effective only if collected oil is successively removed.

3. DESIGN

Commercially available skimmers exhibit a wide variety of working principles applied in their construction. Accordingly, it is very difficult to categorise various existing or proposed designs. Only the principle used for oil pick up from the water surface offers a possibility to distinguish between main groups of skimmers. Two categories (each one with a number of subcategories) can be recognised:

- mechanical skimmers;
- oleophilic skimmers.

These categories are discussed in detail further on in this Chapter.

As regards the autonomy of movement, skimmers can be:

- self-propelled units; or
- non self-propelled units.

Most skimmers fall under the second category which means that they have to be deployed from either a vessel or a shore, but there is also a number of self-propelled units in which the recovery device forms an integral part of a vessel. Self-propelled skimmers are usually very expensive and their use is nevertheless restricted to sheltered, inshore areas. They are most useful in large harbour areas, where they can be used alternatively for floating debris collection.

Recovery units are sometimes categorised in accordance with the relative speed of the skimmer in relation to the water body on which it operates. The relative speed may be zero or different from zero, and skimmers are accordingly divided into:

- static skimmers;
- dynamic skimmers.

This categorisation has not proved very useful, since a lot of skimmers can be used in either way. It is worth noting that there are actually a very limited number of strictly dynamic units.

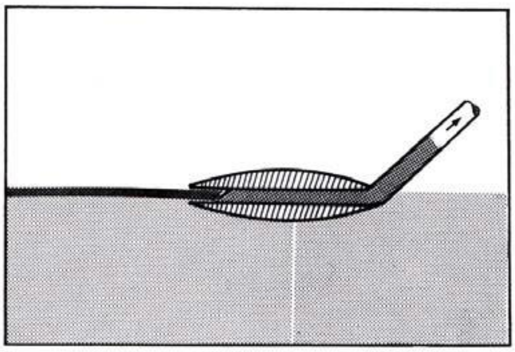
All skimmers need some kind of a transfer system for recovered oil (pump or vacuum unit, hoses, couplings). This system is often incorporated in the skimmer itself but it can also come as a separate unit, i.e., a skimming head can be attached to an independent, external pump.

3.1 Mechanical skimmers

All the devices that are based on fluid flow properties of oils and oil/water mixtures, as well as on difference in density between pollutant and water, are included in the **mechanical** group of **skimmers**. Different working principles applied to make use of above mentioned physical properties of oils further determine four main subcategories of mechanical skimmers:

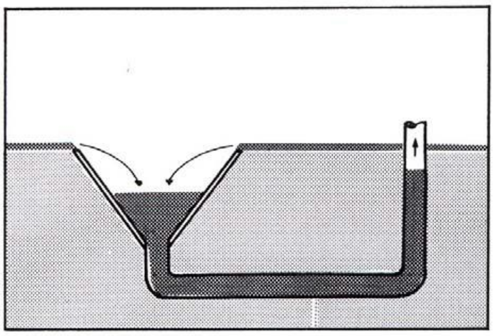
a) **Direct suction skimmers**: skimming head or nozzle floating or held on the water surface directly sucks the surface layer of pollutant.

Figure 1 Operating principle of direct suction type skimmer



b) **Weir skimmers**: weir positioned slightly under the water surface enables the gravity flow of oil into the well of the skimmer from where it is pumped to storage.

Figure 2 Operating principle of weir type skimmer



c) **Vortex (centrifugal) skimmers**: whirlpool (vortex) created by either movement of the skimmer or by an impeller concentrates oil at the centre of the vortex, from where the oil is successively pumped.

Figure 3 **Operating principle of vortex type skimmer**

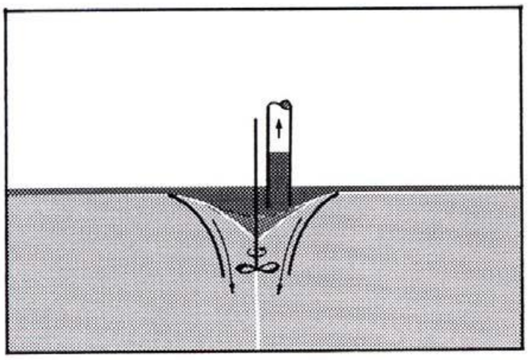
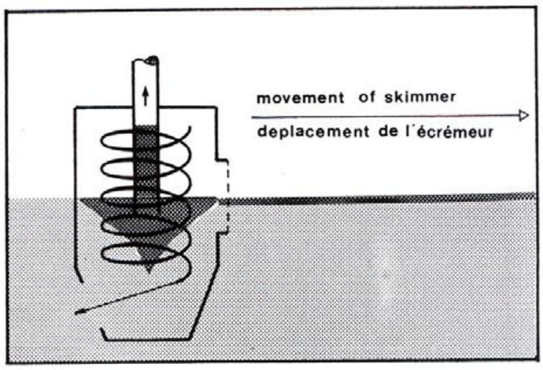


Figure 4 **Operating principle of dynamic vortex type skimmer**



d) **Conveyor belt skimmers**: an inclined (non-oleophilic) conveyor belt transports oil to the collection area (well). Oil is usually forced beneath the water surface (submerged) and towards the recovery well, where it rises back to the surface due to its lower density. Skimmers of this type are sometimes also called **submersion** type skimmers. Some other conveyor belt type skimmers transport the oil directly upwards from the sea surface to the collection well.

Figure 5 **Operating principle of conveyor belt, submersion type skimmer**

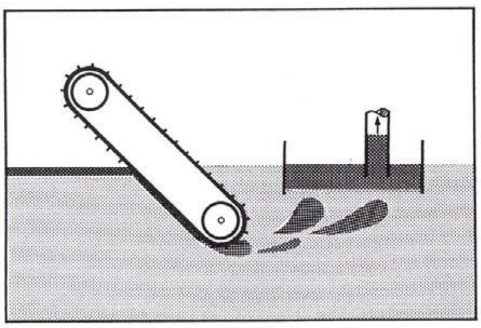
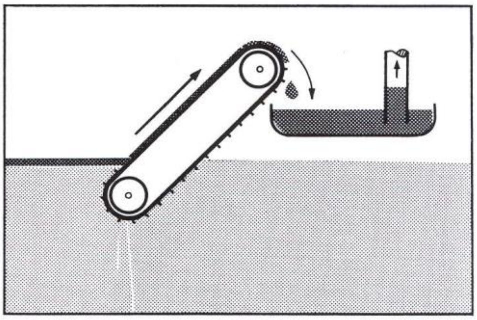


Figure 6 Operating principle of conveyor belt skimmer

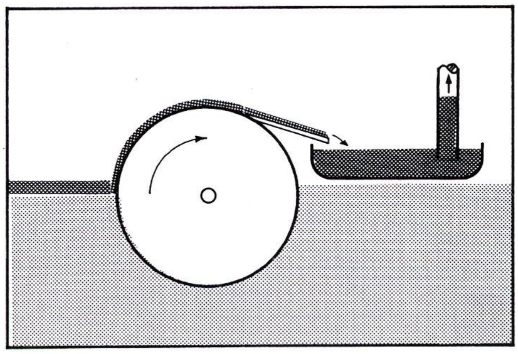


3.2 Oleophilic skimmers

Oil recovery principal of the second main category of skimmers is based on the characteristics of certain materials that have greater affinity for oil than for water. Such materials are known as oleophilic and consequently skimmers that make use of this characteristic are called **oleophilic skimmers**. Stainless steel, aluminium and some plastic materials (for example, polypropylene, polyurthane) are commonly used in the construction of this type of recovery devices. In accordance with the shape of the moving surface to which the oil adheres, four subcategories can be recognised.

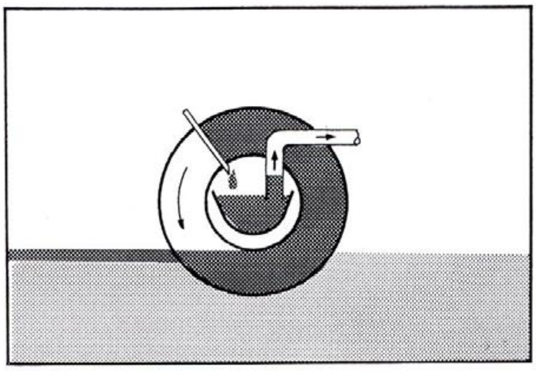
a) **Drum** type **skimmers**: oil adheres to the rotating horizon- tally positioned and partly submerged drum coated with some kind of oleophilic material. Rotation of the drum carries the oil towards the scrapers that remove it from the drum surface and deposit it into a container from where it is pumped to storage facilities.

Figure 7 Operating principle of drum type skimmer



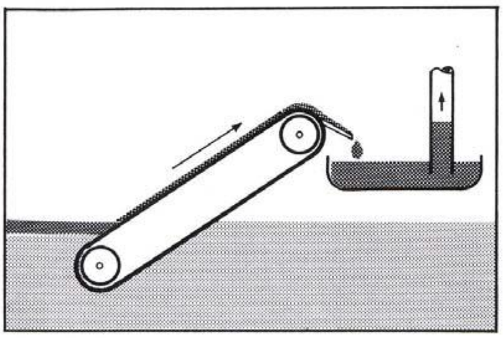
b) **Disc skimmers**: a large family of disc skimmers includes different devices consisting of a variable number of rotating discs made of an oleophilic material. Similarly to drum skimmers, oil which sticks to disc surfaces is wiped by scrapers which direct it into a well (sump, container) from where it is successively pumped out.

Figure 8 **Operating principle of <u>disc</u> skimmer**



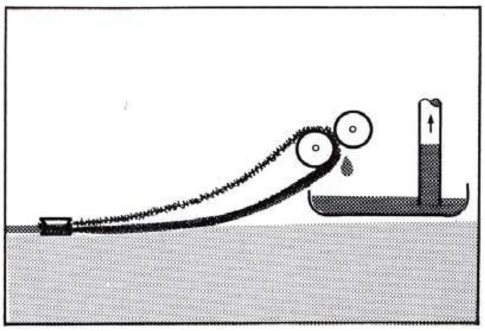
c) **<u>Oleophilic belt skimmers</u>**: oil adheres to the partly submerged belt made out of an oleophilic material and is carried by the belt movement to the upper part of it, where it is removed either by a scraper (wiper blade) or a squeeze roller.

Figure 9 **Operating principle of <u>oleophilic belt</u> skimmer**



d) **<u>Oleophilic rope skimmers</u>**: utilise a floating oleophilic rope which either revolves between two pulleys (one drive pulley and another "tail" pulley) or is suspended above the water surface from a vessel, or is trailed on the water surface by a vessel. The first two types are continuously passing through a set of squeeze rollers which removes adhered oil, while the third one is periodically wrung by a similar device after being saturated with oil. The oil collected in the well (sump) is subsequently pumped to a storage facility.

Figure 10 *Operating principle of <u>oleophilic rope</u> skimmer*



3.3 Skimming barriers

There is a group of recovery units which cannot be included strictly in any of the above mentioned categories, since they are a combination of boom and skimmer, using boom to concentrate oil and some kind of skimming device to remove it from the water surface. They have already been referred to in Chapter 7 as single and/or multi vessel systems for oil collection, but it seems more accurate to include and discuss them together with skimmers as their main function is oil removal from the sea.

Skimming barriers, as this type of recovery units are normally called, comprise a section of boom with an integrated skimming device or a separate skimmer (usually of direct suction or weir type) associated with the boom. Other indispensable parts of such a unit include a pumping system for the transfer of collected oil and a storage facility. Types of transfer pumps may vary from one design to another, but whatever pump is used it should be able to transfer oils and oil/water mixtures of various viscosities and should not be particularly susceptible to floating debris. Their capacities should correspond to the maximum envisaged encounter rate of the unit. Hoses should have sufficient diameter (approximately 100 mm) to allow a continuous flow of high viscosity products. A storage capacity for the recovered oil can be provided either by the vessel from which the skimming barrier is deployed or it can be towed behind the vessel.

It is obvious that skimming barriers are intended for use in open seas or in polluted zones which are big enough to allow larger size vessels to navigate.

Skimming barriers have considerably high encounter rates, can operate in medium seas and are easy to deploy, but their efficiency is limited by the manoeuvrability of vessels from which they are deployed. Low operational speeds required for their use (approx. 1.0 to 1.5 knots) make the selection of suitable vessels critical. Small coastal tankers, dredgers, tugs and supply vessels are the most likely types of vessels to be used for deployment of skimming barriers.

Figure 11 Skimming barrier with incorporated skimming device deployed from a single vessel

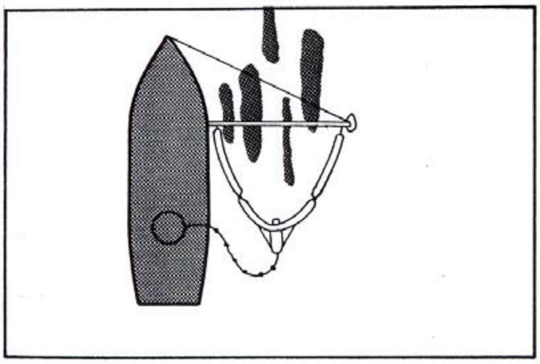
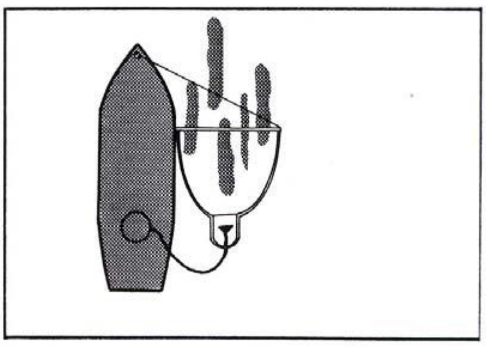


Figure 12 Possibility to combine a boom and a separate skimmer; assembly deployed from a single vessel



4. USE OF SKIMMERS

There are two basically different modes of skimmers' use:

- Oil recovery in open seas.
- Inshore oil recovery (coastal areas, harbours, etc ...).

The main difference between these modes is associated with logistic support required for each of them rather than with the type of equipment used. In other words, most of the skimmers of both types described in paragraph 3 can be used either offshore or inshore (excluding skimming barriers which are mostly used in open waters), but where and how they are going to be used will depend on several factors which are briefly discussed below. Obviously it will not be possible to use certain large skimmers in very shallow waters and places with restricted approach, simply because of their dimensions and weight, likewise the use of some small, portable devices would be ridiculous offshore.

There is a list of limiting factors that determine the use of skimmers both offshore and inshore. These factors include:

- nature of spilled oil;
- size of the spill;
- availability of:
  - skilled personnel,
  - energy sources,
  - auxiliary equipment;
- availability of facilities for maintenance and repairs of equipment;
- availability of time.

4.1 Oil Recovery in Open Seas

Presuming that the above mentioned conditions render the use of a given type of equipment feasible, some specific restrictions will have to be considered if offshore use of the skimmer is envisaged.

While in coastal areas, where skimmers can be operated from the shore and intermediate storage of recovered oil and its subsequent transportation for the final disposal can be arranged in such a way that continuous recovery is not hampered by limited storage capa- city, use of skimmers in open sea (deployed from a vessel) can be restricted even in the most favourable conditions owing to insuffi- cient storage facilities. Oil recovered in the open sea (usually collected with significant amounts of water) has to be transported to the shore periodically. This operation requires very careful planning taking into account: recovery rates of the skimmers, capacities of the transfer equipment (pumps), capacities of the available tanks (on board vessel or floating flexible tanks), dis- tances from the nearest port(s), speeds of vessels etc ... A way to overcome this obstacle is to deploy skimmer(s) in conjunction with a (coastal) tanker which will provide for sufficient storage capacity for say one working day.

Other limitations for use of skimmers in the open seas will include meteorological conditions and sea state. Although they also do affect oil recovery in coastal areas, their negative effects are likely to be more pronounced offshore.

If, in addition, we consider that it is sometimes difficult even to locate an offshore spill and that oil recovery is not possible during the night or during periods of poor visibility, then the fact that in major past accidents only a small part of spilled oil has been recovered from the open sea, becomes more understandable. Nevertheless, no efforts should be spared in attempts to recover as much oil as possible while it floats offshore; the oil will cause worse ecological and economical damages to the coastal resources. If suitable equipment is available and if there is a chance to implement it efficiently (bearing in mind all above-mentioned restrictions), it should be used.

4.2 Oil Recovery in Coastal Areas

In case of a major or even medium offshore oil spill it is almost absolutely sure that some of the spilled oil will reach the shores. Consequently this oil will have to be removed. Use of manual labour and equipment which is not specifically designed for oil recovery are likely to be extensively used to recover stranded oil from beaches and other types of coastline; skimmers (if available) will have to deal with most of the oil which remains floating near the shore.

In order to make the most of the available equipment, some parameters have to be taken into account. They include:

- characteristics of oil;
- volume of the spill;
- topography of the recovery site;
- movements of the sea surface:
  - waves,
  - currents,
  - tide;
- availability of auxiliary equipment.

The type of spilled oil will automatically exclude the possible use of skimmers that cannot cope with itS debris mixed with oil (likely case near the shore) may reduce the efficiency of certain skimmers and its successive removal has to be provided for.

If only a small volume of oil has to be recovered the use of more selective recovery devices is suggested. On the other hand, if the volume of pollutant is large, the use of heavier equipment with higher recovery rates may be preferred although it would imply the transfer of (usually) large quantities of water (accordingly capacities of transfer pumps should be properly evaluated).

Topography of the recovered site will strongly influence oil recovery operations in inshore waters.

Inaccessibility of the recovery site from land will necessitate either the use of boats for deployment of skimmers or the use of self-propelled units. Since none of these solutions provide for sufficient storage capacities, it will also be necessary to plan the transfer of recovered pollutants precisely, taking into account the same factors as those indicated for recovery at open sea. Conversely if the recovery site is accessible by land the use of direct suction recovery units in conjunction with vacuum trucks, road tanks or honey wagons is recommended. Moreover it may be possible to arrange for temporary storage of recovered oil in an immediate vicinity of the recovery site.

The depth of water near the shore will limit the choice of equipment to those units which have draft smaller than minimal water depths at low tide.

The use of dynamic skimmers may not be possible in small, restricted areas such as coves, small bays or creeks.

The possibilities for boom(s) deployment at envisaged recovery site also have to be evaluated since containment will increase the thickness of oil and consequently the recovery rates of skimmers. On the other hand, if containment is impracticable the complete recovery operation may be ineffective.

Since efficiency of the great majority of skimmers is relatively low if waves are higher than 0.8 to 1.0 metres, and only a few are claimed to be operational in waves of up to 1.0 to 1.5 metres, both swell and short waves will most often render oil recovery impossible. It is worth noting that choppy sea would influence the performance of skimmers much more than a long, regular swell.

Currents can sometimes increase the efficiency of skimmers in coastal waters: they can help to concentrate oil in front of the skimmer. On the contrary, if the current velocity is too high, oil can be swept under the skimmer. In any case, directions and speeds of coastal currents should be determined prior to the selection of most suitable recovery site(s).

Capacities and characteristics of pumps can strongly influence an entire recovery operation. Firstly they have to be compatible with recovery rates of skimmers. Whether they are used on shore or installed on board auxiliary vessels, attention has to be paid to the height and the length of suction and discharge. **Suction hoses should be reinforced against flattening**. Since some of the available pumps may not be specifically built for oil combating purposes, their resistance to oil and corrosion has to be checked. Pumps that are not oil resistant will normally be damaged immediately. Certain pumps (e.g. centrifugal) have a tendency to favour the emulsification of oil and water and consequently their use should be avoided if other types of equivalent capacity are available (e.g. screw, diaphragm). Since the viscosity of recovered oil or water in oil emulsion can sometimes be extremely high, pumps unable to transfer such products would be useless. Actually any selected pump will necessarily only be a compromise between various above mentioned requirements, but complete neglect of any of these requirements can easily cripple the envisaged recovery operation.

5 SELECTION OF SKIMMERS

A very disappointing statement has to be noted first: no such thing as a "universal" skimmer exists. Each type of recovery unit has its own advantages in certain spill situations and its drawbacks in others.

Table 1 gives comparative values of main characteristics of different types of skimmers. These values are empirical rather than theoretical, that is, resulting from operational experience rather than from manufacturers' claims based on calculations and/or laboratory tests. The Table may be used to facilitate the selection of the most suitable type of equipment for a particular oil spill situation, although some of the characteristics (e.g. recovery rates) vary significantly from one make to another.

There are also various criteria reflecting the needs of a potential user that a skimmer has to satisfy for given purpose and they have to be precisely defined in the course of contingency planning process. Comparing these criteria with specifications of each particular piece of equipment will result in the selection of the most adequate skimmer for a given site and envisage conditions. **Table 2** lists criteria that may help in selecting appropriate skimmers.

Table 1 Characteristics and limitations of different types of skimmers

GROUP	*TYPE*	*LIMITATIONS*			*SELECTIVITY* (percentage of oil in total liquid recovered)	RECOVERY RATES* (OIL plus WATER)
		TYPE OF OIL	**SENSITIVITY** *TO SEA STATE*	**SENSITIVITY** *TO DEBRIS*		
MECHANICAL	DIRECT SUCTION	ALL KINDS	Sensitive to waves; Used only inshore	Very sensitive	Poor selectively (0 – 80%)	5 – 200 m^3/h
	WEIR	ALL KINDS except very viscous emulsions	Sea State ≤ 2	Very sensitive	Poor selectively (0 – 80% maximum in calm waters)	1 – 50 m^3/h
	VORTEX/CENTRIFUGAL	NON VISCOUS OILS (< 1000 CsT)	Sea State ≤ 2	Sensitive	Good selectivity (40 - 80 %)	5 – 700 m^3/h
	CONVEYOR	ALL KINDS	Sea State ≤ 2	Not sensitive	Good selectivity	1 - 300 m^3/h
OLEOPHILIC	DRUM	ALL KINDS except very viscous emulsions	Sea State ≤ 3	Sensitive	Very good selectivity (50 - 90%)	1 – 60 m^3/h
	DISC	ALL KINDS except viscous emulsions (≤ 3000 cSt)	Sea State ≤ 3	Sensitive	Very good selectivity (50 - 90%)	1 – 400 m^3/h
	BELT	NON VISCOUS OILS (< 1000 cSt)	Sea State ≤ 1	Sensitive	Very good selectivity (50 - 90%)	10 – 300 m^3/h
	ROPE	LOW AND MEDIUM VISCOSITY OILS	Sea State ≤ 3	Sensitive	Very good selectivity (40 - 90%)	1 – 50 m^3/h
	SKIMMING BARRIERS	ALL KINDS except viscous emulsions (≤ 5000 cSt)	Sea State ≤ 4	Sensitive	Fairly good selectively	1 – 500 m^3/h

* Figure vary significantly depending on the design and the size of the un

Table 2. Criteria for selection of skimmers

1. OIL RECOVERY CRITERIA

- Recovery rate
- Selectively (percentage of oil in mixture collected)
- Sensitivity to the type of oil
  - specific gravity
  - viscosity
- Sensitivity to:
  - debris
  - thickness of the slick
  - currents
  - waves (choppy sea, swell)
  - winds.

2. RELIABILITY CRITERIA

- Sea worthiness
- Complexity of the mechanism
- Solidity
- Possibility and simplicity of "on site" repairs

3. STORAGE AND UTILISATION CRITERIA

- Transport and loading requirements
- Operational requirements (personnel and materials)
  - number of operators
  - containment systems (booms, water jets …)
  - pumps
  - power sources
  - handling facilities
  - naval supports
  - storage for recovered pollutants
- Speed of deployment
- Dimensions, draft, freeboard

4. MAINTENANCE AND COST CRITERIA

- Wear resistance of the material(s)
- Resistance of the material(s) to chemical action of pollutant(s)
- Ease of cleaning, maintenance and repairing by not necessarily qualified operators
- Price and delivery times (if possible, terms of lease or hire)
- Manufacturer's warranty

Chapter 9

DISPERSANTS AND THEIR USE

1. GENERAL NOTIONS ON DISPERSANTS

1.1 Definition

Oil spill dispersants are mixtures of surface-active agents in one or more organic solvents, specifically formulated to enhance the dispersion of oil into the sea-water column by reducing the interfacial tension between oil and water. Natural or induced movement of water causes a rapid distribution within the water mass of very fine oil droplets formed by the dispersant action, thus enhancing the biodegradation processes. At the same time, oil that is dispersed is no longer subject to the action of wind that makes it drift towards the coast or other sensitive areas. Moreover, dispersants prevent coalescence of oil droplets and reforming of the oil slick.

1.2 Nomenclature of dispersants

The nomenclature of dispersants is based on three dispersant classification systems, currently used in the world. The following table gives a comparative presentation of these systems:

Table 1. Nomenclature of dispersants

STANDARD NAME	NAME BY GENERATION	NAME BY TYPE	MODE OF APPLICATION	TYPE OF SOLVENT
Detergents Degreasing agents Industrial cleaners	1st	-	Undiluted (neat), from vessels	light aromatic hydrocarbons
Conventional dispersants	2nd	1	Undiluted (neat), from vessels	non-aromatic hydrocarbons
Concentrate dispersants	3rd	2	diluted, from vessels	oxygenates (e.g. glycol ethers) and non aromatic hydrocarbons
		3	Undiluted (neat), from vessels and/or aircraft	

It should be noted that nowadays the first above-quoted category of products ("detergents") are not used as oil spill dispersants and hence are only mentioned for historical reasons and for reference purposes.

1.3 Composition of dispersants

Oil spill dispersants are composed of two main groups of components:

- surface active agents (surfactants)
- solvents

Surfactants are chemical compounds whose molecules contain both hydrophilic and oleophilic groups. Those with a predominantly oleophilic character tend to stabilize water-in-oil emulsion, while those with mainly hydrophilic character stabilize oil-in-water emulsions and these are usually used in formulating dispersants. Surfactants are divided in 4 (four) groups (anionic, cationic, nonionic and amphoteric). However only nonionic and anionic surfactants are used in modern dispersant formulations:

- nonionic surfactants: sorbitan esters of oleic or lauric acid, ethoxylated sorbitan esters of oleic or lauric acid, polyethylene glycol esters of oleic acid, ethoxylated and propoxylated fatty alcohols, ethoxylated octylphenol.

- anionic surfactants: sodium dioctyl sulfosuccinate, sodium ditridecanoyl sulfosuccinate.

Two or more surfactants are often combined in order to improve the performance of the final product.

Solvents are liquid chemicals or their mixtures added to dispersants in order to dissolve solid surfactants, to reduce the viscosity of the product thus enabling uniform application, to enhance the solubility of the surfactant in the oil and/or to depress the freezing point of the dispersant. Solvents may be divided in 3 main groups: (a) water, (b) water miscible hydroxy compounds and (c) hydrocarbons. Hydroxy compounds used in dispersant formulations include ethylene glycol monobutyl ether, diethylene glycol monomethyl ether and diethylene glycol monobutyl ether. Hydrocarbon solvents used in modern dispersants include odourless, low aromatic kerosene and high boiling solvents containing branched saturated hydrocarbons.

A number of dispersants in use today, are marketed as biodegrading dispersants. These are formulated with the addition of nutrients (nitrogen, phosphorus) which promote the natural biodegradation processes by micro-organisms present in the sea water.

The two groups of modern dispersants have approximately the following composition:

- Conventional (2nd generation) dispersants:
  - 10 to 25% surfactant
  - hydrocarbon solvent

- Concentrate (3rd generation) dispersants:
  - 25 to 60% surfactant
  - polar organic solvent or mixed with hydrocarbon solvent

2. DISPERSANTS USE IN OIL SPILL RESPONSE STRATEGY

The use of dispersants in oil spill response has a number of advantages:

- dispersants can be used under a wider range of weather and sea conditions than other commonly used combating techniques;

- it is often the quickest response method;

- by removing the oil from the surface it helps to stop the wind drift of the oil slick, thus restricting the movement of oil;

- it reduces the risk of shore contamination;

- it reduces the possibility of contamination of sea birds and mammals;

- it inhibits the formation of "chocolate mousse";

- it enhances the natural degradation of oil.

The use of dispersants also has its disadvantages:

- by dislocating the floating oil into the water column, it may adversely affect certain parts of biota which would not be reached by oil otherwise;

- if dispersion of oil is not achieved, effectiveness of other response methods on oil treated by dispersants decreases;

- it has no effect on oils with viscosity higher than approximately 2000 cSt at ambient temperature;

- if used near the shore and in shallow waters, it may increase the penetration of oil into the sediments; similarly, if suspended sediments are present, dispersants facilitate the adhesion of oil to the particles;

- it introduces an additional quantity of extraneous substances into the marine environment.

Possibility of properly balancing these advantages and disadvantages decreases in an emergency situation, and accordingly the use of dispersants and its place in a general response strategy for oil spills needs to be defined in advance. Where and under which circumstances the use of dispersants will be given priority over other available combating methods needs to be analysed and decided during the preparation of the contingency plan. By evaluating different interests for each particular zone, geographical boundaries may be defined within which dispersants may or may not be used. As a general guideline, dispersants should not be used in the areas with poor water circulation, near fish spawning areas, coral reefs, shellfish beds, wetland areas, and industrial water intakes.

When such a general policy has been adopted in advance, a final decision on the use of dispersants in a spill situation will have to be taken only on the basis of given circumstances (type of oil, conditions, availability of material and personnel, etc.). Preparing decision trees to help responsible officers greatly facilitates this process.

Taking the decision on the use of dispersants is one of the priorities in each spill situation since relatively shortly after the spillage most oils will not be amenable to chemical dispersion.

Once the decision to use dispersants has been taken, the strategy of their use becomes decisive for the positive outcome of the operation. Some basic principals in this regard can be defined:

- dispersants should be applied to the spill as early as possible;

- dispersants should be applied to thick and medium thick parts of the slick and not to the low thickness areas (sheen);

- treatment should be methodical, in parallel and contiguous or slightly overlapping runs;

- it is important to treat the slick against the wind;

- if the oil is approaching a sensitive area, dispersants should be applied to the part of the slick nearest to it;

- vessels are suitable for treatment of smaller spills near the shore, but the aircraft permit a rapid response (less than 24 hours after the spillage), in particular when large offshore spills are concerned;

- regardless of whether dispersants are sprayed from vessels or aircraft, spotter aircraft should be used for guiding them and assessing the results;

- the dispersant spraying operation should be terminated when the oil reaches the state of weathering (viscosity, mousse formation) in which it is not readily dispersed any more.

Visual aerial observation, complemented with photography, video recording or using one of the available remote sensing techniques should be used for evaluating the results of the application of dispersants. Such reports and records can be also used for record keeping purposes.

In case of a massive oil pollution affecting an extensive area, it is possible and often necessary to use a combination of spill response methods. In such situations dispersants can be used on one part of the slick at the same time when oil is mechanically recovered on the other end of it.

Massive oil spills also often necessitate international co-operation. Application of dispersants may be a part of the assistance offered to a country confronted with such a spill. In order to facilitate inclusion of offered assistance in the national response activities, some countries or groups of countries (Bonn Agreement countries) have agreed to mutually accept in case of emergency application of products approved for use by each country.

Finally, countries which decide to use dispersants as a part of their oil pollution response strategy need to pay particular attention to:

a) storage of sufficient quantities of selected and approved products;

b) procurement and maintenance of adequate spraying equipment;

c) training of personnel on all aspects of dispersants use, including organizing practical exercises at regular intervals.

3. FACTORS AFFECTING DISPERSANT ACTION

Regardless of the application **technique** (Paragraph 8) and **dosage** used (Paragraph 7), dispersant action will primarily be determined by:

- type of oil to be treated
- contact dispersant/oil
- mixing
- weather conditions.

3.1 Type of oil

Characteristics determining the **type of oil** which can be chemically dispersed are basically:

a) viscosity
b) pour point

Only oils with **viscosity <u>at seawater (ambient) temperature</u>** of not more than 2000 cSt (most fresh crudes, medium fuel oils) are considered to be chemically dispersable by presently existing products. Chemical dispersion of oils with viscosity above 2000 cSt (heavy, weathered and emulsified crudes, heavy fuels) is very little or not effective. Even oils with low initial viscosity are likely to reach the limit of 2000 cSt quickly (approximately 24 hours from the moment of spillage), due to the weathering process.

Oils with a high paraffin (wax) content i.e. with a high **pour point** can cease to be dispersable if ambient temperature is significantly lower than their pour point.

Water-in-oil emulsions ("chocolate mousse") do not react to dispersants.

3.2 Contact dispersant/oil

In order to achieve a good dispersant/oil contact, a dispersant needs to be sprayed onto the floating oil in such a way as **to reach the surface** of oil and **not to penetrate** through the oil layer. These goals are achieved by combining appropriate spraying technique (Paragraph 8) and appropriate droplet size. Optimal droplet size is considered to be in the range of 350 and 800 µm, or approximately 500 µm. Smaller droplets will be carried away by wind and may never reach the oil, while the bigger ones penetrate through the oil layer and enter directly in contact with the water without having sufficient time to bind themselves to the oil. Although it is difficult to control precisely the size of droplets, most spraying systems presently in use are designed to produce droplets in the above-mentioned range.

3.3 Mixing

Once the dispersant has come in contact with oil and the oleophilic end of its molecule has been attached to oil, the dispersant/oil mixture needs to be agitated in order to be broken down in droplets and dispersed in the sea-water mass. Either **natural** or **induced mixing energy** is necessary to achieve this goal.

In most circumstances natural agitation of the sea surface (waves) will be sufficient for completing this process (sea state 2, Beaufort 3), however, if the wave energy is insufficient (very calm sea), the mixing of dispersant/oil system and water can be achieved:

- by sailing through the oil slick and stirring it with bow wave and propeller action;
- by mixing oil and water with fire hoses;
- by using specially designed devices for agitating the sea surface (breaker boards, plastic chains).

When the dispersant is applied from a bow-mounted ship's spraying system, mixing energy is provided by bow wave created by the spraying vessel itself.

3.4 Weather conditions

Chemical dispersion of oil is less affected by adverse **weather conditions** than other spill response methods (e.g. containment and recovery). In addition, weather conditions do not directly affect the physicochemical process of dispersion, but rather the application of dispersants.

Winds may blow dispersants away from the target area and consequently cause significant loss of product. In case of the aerial spraying of dispersants, high winds may also affect the safety of aircraft.

Waves generally help dispersion of treated oil. However beyond sea state 5 oil is likely to be covered by breaking waves, which results in a loss of product since the dispersant comes in contact with water rather than with oil.

Poor **visibility** affects dispersant action only indirectly through impeding spraying operations.

4. PHYSICAL CHARCTERISTICS OF DISPERSANTS

Physical properties of dispersants are only of academic interest to a user and the majority of countries that have established approval procedures do not use them as criteria. However, dispersants may be distinguished by the following main physical characteristics:

- viscosity
- specific gravity
- flash point
- pour point
- corrosiveness
- stability/shelf life

4.1 Viscosity

The viscosity of a liquid is defined as its resistance to flow. The unit most commonly used in the Mediterranean region for quantifying viscosity is "centistoke" (cSt).

The viscosity of dispersants ranges between 5 and 120 cSt. Conventional dispersants are less viscous than concentrates. Since viscosity has an effect on the dispersant droplets size, it has to be taken into account when aerial spraying is considered. An often quoted classification system divides dispersants into three groups:

A. viscosity less than 30 cSt. Typically hydrocarbon based products.
B. viscosity between 30 and 60 cSt. Usually conventional products with increased content of surfactants.
C. viscosity above 60 cSt. Normally real concentrates, with high surfactant content and non-hydrocarbon solvents.

Products in group C are most suitable, group B products may sometimes be used and group A products are not suitable for aerial spraying.

4.2 Specific gravity

The ratio of the weight of a solid or a liquid to the weight of an equal volume of water, at some specified temperature.

Dispersants have specific gravities between 0.80 and 1.05. Conventional dispersants have generally lower specific gravities (0.80 - 0.90) than concentrates (0.90 - 1.05).

4.3 Flash point

The lowest temperature at which vapours above the volatile substance will ignite in air when exposed to a flame.

Most dispersants have flash point above 60 °C and should be considered as non-flammable.

4.4 Pour point

The temperature below which a specific liquid will not flow.

Pour point of most dispersants is well below 0 °C (-40 to -10 °C) and in the conditions prevailing in the Mediterranean these should never solidify.

4.5 Corrosiveness

Certain components of some dispersants may cause the corrosion of the packages (drums or containers) in which the product is stored over the prolong periods. Accordingly, regulations concerning dispersants in some countries require that the product does not contain such components.

4.6 Stability / Shelf-life

During the period declared by the manufacturer as the shelf-life of the product, its properties should not change. Most manufacturers claim for their product a shelf-life of 5 years or more. It is practically impossible to verify such a declaration and accordingly, the countries who request an indication of the shelf-life of the product in their approval procedure, usually rely on the statement of the manufacturer. (cf. Chapter 13).

5. ENVIRONMENTAL EFFECTS

Environmental effects of dispersants' use are mainly related to: (a) the toxicity of dispersants or oil/dispersant mixtures; (b) their influence on microbial degradation of spilled oil; and (c) their effects on seabirds and marine mammals populations.

5.1 Toxicity

Toxicity is defined as the inherent potential of the capacity of a material to cause adverse effects in a living organism. It is a relative measure, influenced by many factors, including in particular concentration, duration of exposure, and type of organism.

Toxicity is usually expressed as an effect concentration at a specific time, or as an effect time at a specific concentration. Most often, effect concentrations are expressed as parts per million (ppm) or parts per billion (ppb) and these units are used interchangeably with mg/litre and µg/litre, respectively, minor differences in exact concentrations notwithstanding.

Toxicity of dispersants would be ideally tested *in situ* and on actually present organisms. However, the impracticability of such field tests has led to the development of numerous laboratory testing procedures. Results of such tests should be interpreted very cautiously since the tests are not intended to be ecologically realistic or to predict effects of using dispersants in the field. Most tests use concentrations and exposure duration which substantially exceed expected field exposures. In addition, animals are exposed to more or less constant concentrations for several days, while in the sea initial concentrations of dispersant and/or dispersed oil would be diluted progressively and generally rapidly. Moreover, major errors in interpreting laboratory test results may also originate from the fact that thresholds are most often reported as nominal concentrations (total amount of dispersant or oil divided by the total volume of water in the experimental chamber) rather than measured concentrations of materials to which organisms are actually exposed.

Notwithstanding the above-mentioned restrictions, numerous studies carried out over the past 25 years clearly revealed the basic aspects of dispersant toxicology. Main factors influencing the **toxicity of dispersant** appear to be the following:

- **Physicochemical factors:**

  Surfactants - All surfactants are toxic in high concentrations. Tests show that anionic surfactants are generally more toxic than nonionic ones or esters.

  Solvents - Solvents were the most toxic components of early formulations due to their high aromatic hydrocarbons contents. Those used in current dispersants (cf. para. 1.3) are far less toxic. Toxicity decreases in the order: aromatic hydrocarbons > saturated hydrocarbons > glycol ethers > alcohols.

- **Biological factors:**

  Species - different species show different sensitivity to dispersants. Sensitivity to water based dispersants falls in the order: crustaceans < bivalves < fishes. Sensitivity to petroleum based dispersants falls in the reverse order: fishes < bivalves < crustaceans.

  Life history stage - it appears that young life stages (eggs, embryos) are more sensitive to dispersants than older ones.

  Physiological factors - susceptibility to dispersants varies with seasonal variations, previous exposure, acclimation, health and feeding state.

- **Temperature:**

  Dispersants become less toxic with lowering of temperature. The same phenomenon occurs with dispersed oils. There are significantly higher sensitivities of organisms in warmer waters and in summer as compared to winter conditions.

Lethal concentrations of dispersants have always been the main concern and most toxicity tests aim at determining these. However certain sublethal effects including changes in reproduction, behaviour, growth, metabolism and respiration may also occur when organisms are exposed to levels well below lethal thresholds. Behavioural responses such as cessation of feeding, slowed swimming, disorientation, impaired locomotion and paralysis have been recorded. Surface membranes and tissues, particularly gills, are likely to be most affected by exposure to dispersants (surface active component).

It is to be emphasized that these responses have been noted in laboratory experiments where the duration of exposure are 1 to 4 days longer than those expected in most dispersant use situations in open water, and exposure concentrations of reported sublethal effects normally are 1 or 2 orders of magnitude above highest anticipated concentrations in field use.

Few reports exist of measurements of concentrations following the use of dispersants in the field, however, these suggest that even initial concentrations in the water column are below most, but not all, estimated lethal and sublethal concentrations derived from experiments.

In conclusion, results of studies investigating the effects of dispersants suggest that major effects should not occur in the near-surface waters due to a dispersant alone, provided properly screened dispersants are used at recommended application rates.

The **combined effects of dispersant and oil** may be additive (a sum of effects caused by each of these separately), more than additive (synergistic) or less than additive (antagonistic).

Toxicity of oil is mostly related to that of its "water soluble fraction" (WSF), and there is evidence that the toxicity of WSF of oil and of dispersed oil is more or less the same. Unfortunately, about two thirds of literature published prior to 1987, instead of giving values for oil concentration in water phase, uses nominal concentrations, rendering results of these studies of little use. Tests in which WSF is measured and used as a basis for calculating toxicity generally show no difference between physically and chemically dispersed oil. Moreover, these tests rarely show the evidence of synergism between oil and dispersant, thus validating the general conclusion that oil is as acutely toxic as dispersed oil.

Apparently greater toxicity of chemically dispersed oil is likely to be a result of exposure and not of a greater inherent toxicity.

Results of tests designed to **compare dispersant toxicity to dispersed oil toxicity** suggest that dispersed oil is more toxic when a relatively non-toxic dispersant is used and that a dispersant alone is more toxic when a toxic formulation is used.

5.2 Microbial Degradation

Dispersion of oil, either mechanically or chemically, renders oil more available to microorganisms present in the sea water. The influence of dispersants on microbial degradation of oil is hence of prime importance.

Microorganisms able to grow on petroleum hydrocarbons are present in all sea waters, and the rate of microbial degradation is directly related to the degree of oil dispersion. Paraffinic and aromatic fractions of oil are biodegradable, while for asphaltenes it has not been proven beyond doubt. There is no evidence of biodegradation of polar fractions, nitrogen-, sulphur- and oxygen-containing compounds.

Dispersants increase the rate of oil biodegradation through:

- increasing surface to volume ratio of oil;
- reducing the tendency of oil to form tar balls or mousse;
- enabling dispersed oil droplets to remain in the water column instead of beaching or sedimenting.

Dispersant may however, also reduce the rate of biodegradation by:

- adding new bacterial substrate (the dispersant) that may be more attractive to microorganisms than oil;
- increasing dispersed oil concentrations in the water column, which may have temporary toxic or inhibitory effects on the natural microbial populations.

As in the case with toxicity, most of the knowledge of dispersed oil degradation is limited to results of laboratory or other small-scale studies. Some laboratory studies and all mesocosm studies have shown an increase in rates of oil biodegradation when dispersants are used. Temporary inhibition of biodegradation with dispersed oil was also recorded in laboratory tests. However it appears to occur at dispersed oil concentrations higher than expected in the field. Data from pond and mesocosm studies strongly indicate that effective use of dispersants would increase the biodegradation rate of spilled oil. The question whether dispersants enhance the extent of biodegradation needs to be further studied, although available information suggests that refractory compounds would remain undegraded despite the addition of dispersants.

5.3 Effects on Seabirds and Marine Mammals

Oil affects seabirds and marine mammals due to:

- toxic effects of either direct ingestion of oil from the sea surface or indirect ingestion through grooming or preening.
- effects on the water-repellency of feathers or fur needed for thermal insulation.

Reduction of these effects by use of dispersant has not been studied extensively.

Review of available studies indicates similar response of seabirds to oil components in chemically and mechanically dispersed oil. Response to oil and dispersed oil appears to be similar. However, there is an obvious need to reduce surface oiling for bird protection. Exposure to dispersants and dispersed oil seems to be a greater problem than enhanced toxicity of oil.

It is known that marine mammals are affected by exposure to oil. The effects reported include the dysfunction of physiological processes such as thermoregulation, balancing and swimming ability as well as impairment of biochemical processes such as enzyme activity. Other overt effects such as eye irritation and lesions have also been reported. Exposure of marine mammals to oil can lead to changes in the ability of animals to deal with the uptake, storage and depuration of hydrocarbons whilst acute exposures can result in mortality in particular with young mammals which are more susceptible to the toxicological effects of oil.

Oiling causes reduction in fur insulating capacity and dispersants have been experimentally used for the removal of crude oil attached to fur. These experiments resulted in the removal of natural skin oils together with crude thus destroying the fur's water-repellency. Surfactants can increase the wettability of fur or feathers, allowing cold water penetration and subsequent increase of the thermal conductance. This is particularly dangerous to animals that are buoyed or insulated by their fur or feathers. Records of animal deaths due to direct ingestion of oil during grooming also exist. Extremely limited information on the influence of dispersants or dispersed oil on marine mammals, nevertheless suggests that use of dispersants may not reduce the physical threat of spilled oil to some fur-insulated sea mammals.

6. TESTING, ASSESSMENT AND SELECTION OF DISPERSANTS

Indiscriminate use of dispersants in combating oil spills may have deleterious effects on the marine environment and therefore most of the countries, which consider the use of dispersants as a part of their oil spill response strategy, have developed certain criteria or specifications with which dispersants should comply.

These specifications may be used for the selection of the most adequate products on an informal basis, while some countries have established formal approval criteria.

For the moment, there are no agreements between national authorities on these criteria, although certain steps have been taken in this direction within, for example, the Bonn Agreement.

Most often the specifications are based only on the effectiveness and toxicity testing of products. In addition, some countries have set standards on the biodegradability of the product and/or dispersed oil. There are also countries which specify required physical characteristics of dispersants which may be used.

On the basis of screening tests for any of these characteristics, individual competent national authorities develop their lists of approved products, which might be used in conformity with decided response strategy.

There is also no agreement on testing procedures between different national administrations. However, regardless of the tests chosen, these should allow for ranking of products with regard to their relative effectiveness, toxicity or biodegradability.

All known testing procedures are based on laboratory tests. Such tests are not aimed at simulating real field situations and are accordingly designed to give relative values of tested properties. Field experience shows that there are no significant discrepancies between relative values obtained in laboratory tests and behaviour of tested products in the field, although differences sometimes appear. The same applies to the comparison between results of different tests: although absolute values can largely differ for a specific characteristic of a tested dispersant, depending on the testing procedure used, products which show better results according to a certain procedure, normally also appear superior when tested in accordance with another procedure.

The main concern in the early years of dispersants' use was their toxicity. It is understandable when some disastrous effects of using first generation products (having a high aromatic contents) is taken into consideration. With the development of new, much less toxic formulations, more and more attention has been paid to dispersants' efficiency. At present, the effectiveness of dispersants is the most important selection criteria. It is considered that toxicity, as well as biodegradability, of an ineffective product are irrelevant. The objective is to select a product with the best possible combination of relatively high effectiveness and relatively low toxicity.

Regardless of specific test procedures, a generally accepted testing pattern follows several common steps. The effectiveness of the product is tested first. Products which pass this criteria are then tested on toxicity and biodegradability. Results of toxicity and biodegradability tests are compared, and the products which pass defined criteria are approved for possible use.

6.1 Effectiveness tests

Most of these tests measure the degree of dispersion (droplet size distribution) either by visual observation or by some kind of analytical technique, after mixing oil and dispersants under standard conditions. Mixing energy can be introduced into the water/oil/dispersant system by:

- a pump which circulates the mixture;
- waves created by a moving plate or ring;
- waves generated by an air stream;
- rotating a specified shape flask at a fixed speed;
- various types of stirrers.

The measurement of the lowering of interfacial tension between oil and water following the addition of a dispersant can also be used for the assessment of the dispersant's efficiency.

The effectiveness is sometimes assessed also on the basis of measuring the speed of resurfacing of dispersed oil after mixing.

The differences in results and rankings often originate from differences in the parameters of the tests (type of oil, temperature, oil and water volumes, dose rates, etc.).

6.2 Toxicity testing

Test materials are usually dispersants, dispersed oil (oil/dispersant mixture) and sometimes oil alone. Test species could be fish, arthropods (usually decapod crustaceans), molluscs (pelecypods), annalids (polychaetes) and algae. Ideally, test species should be selected among locally significant populations. Tests may be acute (short term) single species, lethal or sublethal.

The main goals of these tests are:

a) to determine the relative toxicity of a certain dispersant versus other previously tested products;

b) to assure that dispersants do not significantly increase acute (or chronic) toxicity of dispersed petroleum hydrocarbons;

c) to determine factors that modify dispersant toxicity, or enhance or ameliorate oil toxicity under natural conditions.

Due to the increase of toxicity with the increase of temperature, toxicity tests should take into consideration expected changes in seawater temperature.

Measure of LC 50 in a determined period (usually 24 or 48 hours) is the most common criteria used in toxicity tests.

6.3 Biodegradability tests

Dispersants and dispersant/oil mixtures are often tested for biodegradability. There is no consensus on a standard method for testing biodegradability of dispersants and various adapted standard tests on organic material are in use.

Control of the non-inhibition of biodegradability was introduced by France several years ago, in addition to testing biodegradability alone.

6.4 Other tests

Standard analytical methods are used for testing other properties (density, viscosity, etc.) if so required by the competent authorities.

7. DISPERSANTS' DOSAGE AND APPLICATION RATES

The amount of dispersants which needs to be applied to a certain quantity of oil, in order to achieve a desired level of dispersion, depends on the **dose** (oil/dispersant ratio) recommended by the manufacturer or determined by experiments.

Although recommended doses vary from one dispersant to the other and for each dispersant with the type of oil and its viscosity, in spill situations it is often necessary to apply approximate quantities, calculated on the basis of certain average figures.

In general terms **hydrocarbon based dispersants** are usually applied in doses of approximately 30 - 50 % of estimated oil quantity for low viscosity oil (up to 1000 cSt) and 100% for oils in the viscosity range of 1000 - 2000 cSt. Figures for **concentrate dispersants** are in the range of 5 - 10% for oils of up to 1000 cSt, and 10 - 15% for treatment of oil between 1000 - 2000 cSt. Treatment of oils with viscosities of more than 2000 cSt is considered ineffective.

Required **application rates** also depend on the type of spilled oil, its thickness and prevailing conditions. Since an oil slick does not have uniform thickness and moreover it is difficult to determine it precisely, it is necessary to calculate application rates on the basis of generally accepted rules for the assessment of oil thickness. Dark patches of oil are assumed to be approximately 0.1 mm thick and areas covered by a thin oil sheen are estimated to be between 0.001 and 0.01 mm.

Regardless of the spraying device used, application rate is determined by the discharge rate of dispersant pump, speed of the vessel or aircraft and the width of the area covered by the spray (swath). Relation between these variables is the following:

application rate = discharge rate / speed x swath

Consequently, given the constant swath of the available spraying equipment, the required application rate for each particular slick area can be achieved by either

a) selecting the appropriate discharge rate of the dispersant pump, or by
b) selecting the appropriate speed of the vessel or aircraft.

Very often an average treatment rate of 100 litres of concentrate dispersant per hectare, corresponding to oil thickness of 0.1 mm and a dose of 1:10 is used in approximate calculations for the use of dispersants.

8. DISPERSANT APPLICATION SYSTEM

Selection of the dispersant application technique basically depends on:

- the type of dispersant available
- the type of spraying device available

although the size and location of the spill must also be taken into consideration.

Several dispersant spraying systems exist and they can be grouped in accordance with the carrier for which they were designed:

- portable units for individual use
- boat mounted spraying systems
- aircraft mounted spraying systems

8.1 Portable units for individual use

Light weight, cheap and easily available **back pack units**, normally used in agriculture can also be used for application of dispersants to small spills near the shore or for cleaning rocks. The application rates are limited.

There are designs where the tank and the pump are **trailer mounted** and connected to the portable spraying gun by a flexible hose.

Both hydrocarbon based and concentrate dispersants can be used with this group of devices.

8.2 Boat mounted spraying systems

Several types of this equipment exist including units fixed on the vessel as well as removable ones:

8.2.1 <u>Systems for spraying diluted dispersants</u>

- **Systems** for spraying **hydrocarbon based dispersants** (2^{nd} generation) are rarely used nowadays since these dispersants are sprayed undiluted and due to the 1:1 or maximum 1:3 dispersant/oil rate, a large amount of dispersant needs to be carried on board. They comprise a fixed flow rate pump and 2 spraying arms usually with 3 nozzles each, which need to be stern mounted and thus necessitate the use of cumbersome breaker boards.

- **Eductor systems** are designed to work with the ship's built-in fire-fighting system. The eductor, which is connected to the discharge side of the pump, causes a negative pressure at the point of dispersant intake, thus sucking it in into a discharge line. The diluted dispersant is applied by a fire monitor.

  This system tends to waste the dispersant and has limited encounter rate, and although it is found on most vessels, it should be used only if no other equipment is available.

  Only concentrate dispersants can be used with it.

- **Injection systems** consist of two pumps, one for water and the other, similar to chemical feeder pumps with variable flow rate, for the dispersant. The dispersant is applied through nozzles mounted on spraying arms attached to the vessel's side. Fixed and portable designs exist, and there are units for installation on either the vessel's bow or stern.

  Stern mounted units generally require the use of breaking boards or similar devices for the agitation of the surface on which the dispersant was applied. When the spraying gear is bow mounted, mixing energy is provided by the bow wave.

Injection type systems are suitable only for spraying diluted concentrate dispersants.

8.2.2 <u>Systems for spraying neat dispersants</u>

- **Systems for** spraying **neat concentrates** are usually bow mounted, have a pump with a variable flow rate and the dispersant is discharged also through nozzles mounted on spraying arms. These are usually longer as compared to stern mounted arms, having a greater oil encounter rate. Mixing energy is provided by bow wave.

These units are specifically designed for the application of undiluted concentrate dispersants.

- **The ducted-fan air blower** system is a relatively new addition to boat mounted equipment. Neat concentrate dispersant is injected into a ducted-fan air blower through specially designed nozzles. These units are removable and are usually put on a vessel's bow. Spray can be directed by the operator. Wind strongly affects the direction of the spray.

Different types of vessels may be used for spraying dispersants and, in addition to specially built anti-pollution vessels, these include tug boats, supply vessels, trawlers or small fishing vessels. The necessity to operate at low speeds at the same time retaining the necessary manoeuvrability may be a limiting factor in the selection of vessels. Suitable vessels should also have sufficient storage space for dispersant.

8.3 Aircraft mounted spraying systems

As a result of advantages offered by the aerial spraying of dispersants (good control and assessment of results, rapid response, high treatment rates, optimum use of the product), a number of spraying systems have been developed for use with both fixed and rotating wing aircraft (helicopters). Existing units are either of a type that can be used by the aircraft of convenience or of the permanently installed type. Standard built-in spraying systems of crop spraying aircraft, widely used in agriculture, can be adapted for the spraying of dispersants.

Only neat concentrate dispersants are suitable for use with airborne spraying systems.

8.3.1 Airplanes (fixed wing aircraft)

- **Crop spraying airplanes** are readily available. However, it is advisable to modify the spraying nozzles because the application rate of dispersants is higher than that of agrochemical products. They could not be used far from the shore due to limited tank capacity and insufficient safety offered by a single engine.

- **Fixed systems for** converted **multi-engine aircraft** comprise storage for dispersants, a pump including powerpack spray arms with nozzles and a remote control system.

- **Self-contained airborne spraying systems** are built to suit large transport airplanes which have rear cargo doors able to remain open during the flight. Containerized units comprise tank, power pack, pump and retractable spray arms.

8.3.2 Helicopters

- **Fixed spraying systems for helicopters** are mounted under the fuselage and are made up of the same parts as the units built-in fixed wing aircraft.

- Helicopter **spray buckets** can be used with any helicopter having a cargo hook for underslung loads. Units are self contained (tank, pump, power pack, spraying arms) and remotedly controlled from the cockpit.

Aerial application of dispersants depends on the visibility over the slick area and relies on wave energy for mixing dispersant with spilled oil.

Aircraft permanently equipped for dispersant spraying are rare due to high costs involved and the use of underslung helicopter buckets seems to be the most readily available solution. In addition, the use of helicopters has the advantage of extremely good manoeuvrability but their carrying capacity decreases very quickly when the distance to be covered increases. The selection of fixed wing aircraft is limited by the lowest speed at which the aircraft can operate and which should not exceed 150 knots.

9. LOGISTIC REQUIREMENTS FOR THE EFFICIENT USE OF DISPERSANTS

Regardless of the scale on which dispersants are applied, their use calls for well organized logistic support. This aspect becomes particularly important when dispersants are used for the treatment of massive spills relatively far offshore. Since mechanical recovery of oil also necessitates significant logistic support, logistical constraints may be a decisive factor in deciding whether to use one method or the other. The availability of the necessary equipment, products and personnel will play a key role in taking decisions. However other factors such as the size of the spill and its location, time required for mobilizing equipment and personnel and prevailing sea and weather conditions, will also strongly influence the decision on which method to chose.

If the maximum efficiency of the dispersant treatment operation is expected, particular attention needs to be paid to its logistic aspects:

- treatment of oil with dispersants necessitates the use of significant quantities of the product. It may range from a minimum 10% of the volume of oil which is planned to be treated when concentrate dispersants are used, up to almost the same volume as the volume of oil (100%) to be dispersed, when conventional, hydrocarbon-based products are used. This explains why nowadays concentrate products are almost exclusively used for the treatment of large spills at sea, and the use of hydrocarbon-based products is limited only to small spills near shore.

Stockpiles of dispersants existing in most of the countries are usually planned to be sufficient only for initial response. It is necessary to make in advance arrangements with manufacturers and/or distributors to provide additional quantities of the product at an extremely short notice. The problems arise with smaller manufacturers who usually do not keep large enough supplies and hence are unable to provide sufficient quantities when necessary.

Transportation of these additional quantities of dispersant from the site of storage, production or from the airport of arrival (only airlifting the supplies from one country to another is fast enough to bring dispersants to affected country in time) to the spill site or operations base, needs to be properly planned and precisely executed.

- If large quantities of dispersants are utilized, their transportation from the stores to the operations base in road tankers or liquid containers is more efficient as compared to transportation in drums. High capacity pumps should be used for reloading of spraying units.

- Wear and tear of spraying equipment may be significant and proper maintenance is necessary. This is usually done during the night, when the operations need to be interrupted anyway. The same applies to the maintenance of vessels or aircraft included in the operation. Supplies of the most important spare parts need to be available at the base.

- Fuel for vessels and aircraft needs to be available at the base and refueling operations executed promptly in order not to delay spraying operations.

Problems are often encountered when aerial spraying is used, since in most places the fuel for piston-engine aircraft is in short supply. If local aircraft are used, necessary arrangements for fuel supply are made in advance through the contingency planning process. If aircraft are requested through international assistance, availability of specified fuel needs to be checked prior to making the request.

- Helicopters can land or change the spraying systems, even without landing, almost anywhere. Landing sites for small aircraft can be improvised if proper airfields are not available. However, larger aircraft need long runways and only appropriate airports can be considered as bases for the refueling and reloading of dispersants.

- Accommodation for crews needs to be provided near the base***;*** when larger vessels are used for spraying, this problem is eliminated since the crews are accommodated on board.

- Appropriate communication links, in particular those between spotter aircraft and spraying units, are essential. VHF appears to have advantages over other systems.

- Permanent contact needs to be established with national aviation authorities to obtain clearance for planned operations without delay.

Chapter 10

TREATMENT PRODUCTS OTHER THAN DISPERSANTS AND THEIR USE

1. GENERAL INFORMAITON

Several categories of products can be used at different stages of oil combating operations at sea and on shore.

Objectives for their use are generally the following:

At sea:

a) To facilitate the recovery of oil:
- sorbents
- gelling agents / solidifiers

b) To condition the oil:
- surface tension modifiers
- sinking agents

c) To destroy the oil
- burning agents

On shore:

a) To facilitate the pumping and transfer of oil:
- emulsion breakers / demulsifiers

b) To accelerate the clean-up:
- cleaning agents

c) To increase the rate of the natural degradation:
- biological agents (bioremediation products)

Some of these products have been more or less regularly used during oil spill response operations (sorbents, biological agents, emulsion breakers, cleaning agents), while the others are still scarcely used or are being developed. Sinking agents had been used in the past, however their use has been prohibited since the early eighties.

2. SORBENTS

Sorbents are defined as products that fix liquid oil either by absorption or by adsorption. They can be of both organic and inorganic origin, natural or man-made products. They are available in various forms (powder, granules, pillows, mats, rolls, etc...).

Use of sorbents can sometimes facilitate the removal of oil from the sea surface. The use of (floating) sorbents to fix and agglomerate oil or some other pollutants in case of an accident is an efficient technique widely applied on shore and in ports to recover small contaminations. Cheap and immediately available products that can be used are, for example, sawdust, cotton rags or straw.

The use of sorbents at sea gives rise to technical and logistic problems connected both with the characteristics of the sorbent used and the way of its application. The treatment of a certain volume of oil necessitates the use of at least equivalent volume of sorbent, which hence needs to be supplied, stocked, transported to the zone of incident, applied, recovered after mixing with oil and then disposed of. All these problems render the use of sorbents limited to small or medium size spills in sheltered areas near the shore. Sorbents are often used in shore clean-up operations when more common recovery methods either give poor results or are inapplicable. This refers particularly to the treatment of viscous oils for which few pieces of recovery equipment are efficient and dispersants are useless or to oil slicks close to the shore where the use of dispersants is proscribed. Sorbents are also used to facilitate the collection of oil on shore, on beaches or to complement cleaning of rocks.

2.1 Sorbents in bulk

Sorbents that are used in bulk come as powders, fine particles and short mineral or organic fibres. These are often industrial wastes either raw or treated and conditioned to be used as sorbents. Sorbents are often grouped in three classes:

a) Treated mineral materials:
- expanded perlite,
- vermiculite, ...

b) Treated materials of vegetal origin:
- sawdust,
- wood shavings,
- peat, ...

c) Polymers:
- polyurethane,
- polypropylene,
- polystyrene,
- epoxy resins, ...

2.2.1 <u>Properties of sorbents in bulk</u>

The main properties that need to be considered are:

- Buoyancy
- Selectivity (oil/water)
- Sorption capacity
- Consistency of agglomerates
- Possibility of re-use
- Disposal methods

The technical documents of the manufacturers give two essential data:

i) Specific gravity (usually between 0.04 and 0.3).
ii) Sorption capacity (usually between 0.5 and 1.2 by volume for light oil).

When the last two figures are compared with the price of m^3 of sorbents, it appears clearly that the price range (from 1 to 13) does not correspond to significant performance variations (approximately 1:2).

Although other factors have to be considered (ease of application, quality of the agglomerates, disposal methods), the price of the product appears to be an essential parameter in the choice of the product.

If the use of sorbents at open sea is envisaged, a more complete evaluation of the performance of the products is necessary. The technique generally chosen for collection of saturated sorbents is trawling which is not possible if agglomerates are not stable.

2.2.2 Equipment for application, spreading

The method most often used for obtaining even distribution of sorbents on land slicks is manual spreading from sacks. This method is not practical from vessels at sea except for very small slicks and in fair weather. For larger spills, a hydro-ejector seems to be the best suited application system due to its flow rate, reach, precision and existence of fire fighting circuits on board most ships.

The sorbent's application rate will depend on the performances of the equipment and on the type of sorbent used. Certain products allow for the application rates of up to 2 m^3 of sorbent per minute.

However, application of sorbents by hydro-ejectors causes a decrease in the products' performance, and this was the reason for studying systems for application by air stream. In such a case, it is necessary to use either a spreading boom or a nozzle to direct the sorbent and air stream towards the slick and to limit the loss (waste of material).

2.2.3 Recovery of agglomerated oil

There are still very few recovery systems which can be used in the open sea. Some years ago the French Petroleum Institute (IFP) developed a surface trawl system that has been tested and successively improved during series of trials.

It comprised a trawl net with detachable end (bag) that was towed by two vessels and had an opening of 20 m. The collected agglomerates flow into a bag at the end of the device. This bag (end of the trawl net) could be removed once filled and replaced by an empty one.

The filled bags could either be left aside and later on picked up by another vessel or towed away.

The bags were made in two dimensions: 2 m^3 for lifting by a derrick or a crane and 8 m^3 for towing. At the same time with this system that rendered good results but was heavy to manipulate, another system, much lighter and simpler, had been developed for use with seaweed harvesters. It consisted of a metallic frame connected to a previously described bag by means of a netted funnel.

There are other coastal or harbour systems for recovery of very viscous products and these can also be used at sea if sea state and weather conditions permit.

2.2.4 Use of Sorbents on Shore

Besides the classic uses of sorbents on land or in ports mentioned in the beginning, these have limited use also in the following cases:

- Treatment of oil slicks on sandy beaches in order to facilitate the recovery of oil.
- Fixing of oil released by water flushing during the clean-up of beaches and rocks.

In both cases, the comparison of results obtained using sorbents and using direct recovery methods could not really justify their systematic use considering the difficulties in their application.

The use of sorbents should therefore be restricted to those cases in which more common recovery methods either give poor results or are inapplicable, as well as for prevention, in order to fix the oil, make it less sticky and improve its buoyancy.

2.2 Sorbent booms, pillows, sheets

There are sorbent products made like booms, pillows or sheets which can be used for treatment of very small spills or for final clean-up work, at the end of response operations and after the recovery of oil by other means.

On a small scale, these are easier to use than powders or fine particles, but their efficiency with heavy oils is limited and their prices are too high for the extensive use.

3. BIOLOGIVAL AGENTS

Spilled oil is naturally biodegraded by hydrocarbon-consuming micro-organisms normally existing in the sea water. Biological agents are either lyophilized such micro-organisms (primarily bacteria) or, more often, nutrients (e.g. phosphorus, nitrogen) which increase the growth rate of naturally present micro-organisms.

Although results obtained by using **bioremediation** techniques (the name commonly used for oil spill treatment by biological agents) indicate a significant increase as compared to natural biodegradation rate, the process is too slow to be considered as one of the initial response methods in emergencies. Nevertheless, a great deal of research and development has been done in recent years in this particular field of oil spill response, and the bioremediation is now considered as an effective way of removal of stranded oil from contaminated shores.

4. BURNING AGENTS

Burning agents are products intended to ignite and/or sustain combustion of spilled oil.

Controlled burning of spilled oil on sea surface has often been proposed as a possible response method, however despite obvious inflammability of most hydrocarbons and extensive research in this field, the method has a number of limitations and was never used on a large scale in a major oil spill. The main reasons for relative impracticality of using, as a reliable response option, controlled burning of spilled oil are related to the spreading of oil (the cooling effect of water beneath the oil layer and the subsequent need to concentrate the oil prior to burning), and to uncertainties concerning the effects of combustion. Namely, even if achieved, the burning is never complete resulting in severe air pollution and leaving considerable amounts of heavy partly burnt residue.

5. GELLING AGENTS (SOLIFDIFIERS)

Gelling agents are usually two component polymer products which, when mixed into the spill, incorporate oil in their molecular structure immobilizing and solidifying it. Spreading of solidified oil is thus inhibited and resulting material is easier to handle than liquid oil.

The high cost of gelling agents, large volumes required and problems associated with their application have restricted the use of these products to small spillages in confined areas.

6. SURFACE TENSION MODIFIERS (CHEMICAL BARRIERS)

These products have been designed to inhibit the spreading of oil on sea surface by modifying surface tension properties of oil.

However, their use has been limited by the facts that their efficiency is strongly affected by wave movement and that they are effective for a very short period of time. Surface tension modifiers were also proposed for use on shore (by spraying them on beaches prior to the arrival of oil), in order to prevent coating of pebbles, gravel or stones with oil.

7. SINKING AGENTS

These materials had been designed to adsorb oil to their surface, forming compositions with a density higher than water, thus causing the sinking of oil.

Various materials (sand, volcanic ashes, coal dust, brick powder, clay, etc...) can be used for this purpose, but most of them do not stabilize the sunken oil at the sea bottom. The use of chemically treated (hydrophobic) products assures that sunken oil will not resurface.

The use of sinking agents has generally **been prohibited** because of possible detrimental effects of sunken oil on benthos.

8. DEMULSIFIERS

The treatment of reverse emulsions, created by wave action and/or recovery systems, by demulsifiers enables separation of oil from water and debris incorporated in the emulsion and facilitates considerably pumping and transfer of oil.

Demulsifiers (emulsion breakers) are mixtures of surfactants and solvents, working on oil/water interface.

Necessary doses of emulsifiers vary between 0.05 to 0.1% and their efficiency is directly related to the distribution of the product in the emulsion. They should either be injected into the pump intake or into a special static mixer.

A correct treatment by demulsifiers induces a very quick decrease of viscosity followed by the separation of oil from water and debris in few minutes.

Results obtained in laboratory and through field experiments indicate that:

- The effectiveness of the product depends on the nature of the emulsion;
- The treatment of emulsions of viscous residual oils or high wax crudes (asphaltic) gives poor results;
- All the products are ineffective on emulsions weathered a long time at sea.

Regarding the toxicity of these products, tests indicate that a part of the demulsifier remains in the water phase after separation and that the toxicity of this water should be considered, particularly if the water is to be drained into the sea near the coast.

Concerning the use of demulsifiers in offshore recovery operations, the toxicity should be a less important parameter because of much higher dilution capacity.

Chapter 11

SHORELINE CLEAN-UP

1. INTRODUCTION

In spite of the various methods and techniques deployed to combat an oil spill while the oil is still afloat (offshore), it is most likely that a smaller or a greater part of the spilled oil, will reach the shoreline. Past experience shows that a large number of oil spills and almost all of those occurring relatively close to shores result in a more or less severe coating by oil of beaches, rocks or any other coastal formations.

The decision to clean the affected shoreline (and to what extent) will depend on factors such as:

- the possibility to reduce environmentally detrimental effects of stranded oil;
- the necessity to use coastal zone for commercial purposes (fisheries, tourism, industry, etc ...);
- the probability that stranded oil may (later on) recontaminate another (sometimes more sensitive) part of the coastline;
- the feasibility of clean-up operations.

The method of shoreline clean-up will then be determined by another group of factors including:

- type and quantity of stranded oil;
- type of affected coastline;
- period of the year;
- meteorological conditions;
- accessibility from land or sea and load bearing capacity of the contaminated area;
- availability of personnel and materials.

Both groups of factors have to be considered in a relevant contingency plan. The first group will determine **priorities for protection** and clean-up, while the second will give guidelines for **selection of appropriate clean-up method**. The most efficient way to achieve both of these goals is to map the entire coastal zone indicating the nature of coastline and its importance (viz. areas of ecological interest, fishing areas, fish spawning areas, fish farms, shell fish beds, industrial installations, amenity beaches, yacht marinas, harbours, etc ...). Accessibility to each particular sector and possible temporary storage sites should also be indicated on such maps. These are commonly known as **sensitivity maps**, and exist as either paper or electronic maps.

Decision making process (i.e. the selection of appropriate clean-up methods and of the necessary extent of clean-up actions) is greatly facilitated by using well prepared sensitivity maps, since the only elements that need to be taken into consideration are data specific for that particular spill situation (that is, nature and quantity of oil, period of the year, etc ...). In the absence of a sensitivity map, decision makers will nevertheless have to consider all above mentioned factors before commencing any beach clean-up activity. In such a case, advice from local authorities and population, scientists, etc ... may prove indispensable.

2. GENERAL CONSIDERTATIONS

Whatever the clean-up method selected for a certain site, several considerations will have to be borne in mind by the person responsible for the operation in order to achieve the desired result. The most important ones are listed below:

Sequence of operations and time factor: Oil which has affected a certain part of a shoreline may either be stranded on the beach and fixed there or remain partially floating near the shore. As well, quantities of pollutant may vary from a huge, thick layer to sporadic patches of oil. Consequently attempts should be made to follow a certain sequence of operations:

- removal of large quantities of oil, especially if it is still afloat - if this is not done first, winds, waves, currents and tidal movements can shift the contaminant to another (not affected or more sensitive) part of the coast;

- removal of stranded oil which is fixed on the beach - sometimes it may be wise to delay this step if there is no chance for the already stranded oil to be dislocated and/or if more oil is expected to affect the same beach;

- removal of small, scattered patches of oil.

Once all the oil has reached the beach and a decision to clean the shoreline has been taken, the clean-up operations should commence promptly since a delay will result in stabilizing the oil in sand, on rocks or vegetation, more oil will penetrate (deeper) into the beach material and consequently it will be more difficult and expensive to deal with.

Base / Headquarters: All clean-up operations should be planned and co-ordinated by the On-Scene Commander and his response team. Accordingly, a base or headquarters should be established close to the working area. It should be easily accessible, signposted if necessary, and equipped with necessary telecommunication equipment (telephones, fax, radio) and basic office facilities including a room for briefings, computers, tape recorders, maps, etc. If possible sleeping accommodation for the members of the response team should be close to the base.

Communications: Permanent contact should be kept between the headquarters of the response operation and working (and support) teams involved in a shoreline clean-up operation: supervisors of working teams should regularly report to the base. Portable VHF radio-telephones are standard means of communication between working sites and head-quarters, however cellular (mobile) telephones could also be used. Telephone (fixed or portable) and fax are normally used for long(er) distance communications, and the use of e-mail is becoming increasingly common. On the contrary, telex is nowadays used only occasionally although it remains a valid alternative where available.

Surveillance: As regards all oil spill response operations, a good knowledge of the actual situation is essential for correct planning of future actions. Although problems of obtaining reliable information are less pronounced than in combating oil spills offshore, regular reporting of progress made in clean-up operations has to be established. It may be useful to entrust one experienced member of the response team with this task. Availability of a helicopter or a fixed wing aircraft may prove to be an advantage in obtaining an overall picture of the situation especially if more oil is expected to come ashore.

3. SHORELINE CLEAN-UP METHODS

Several basic methods and techniques for shoreline clean-up, developed on experience of past oil spill accidents, fall under four main categories:

I) Removal of oil and oily material (manual and mechanical).

II) Flushing of oil (with water, although dispersants are used in some countries).

III) Burning of oil and oily material.

IV) Leaving oil to degrade naturally.

Skimmers and sorbents can obviously also be used for oil recovery on shore or near it, however these methods are not discussed here, since principles of their use remain the same as those described in lectures dedicated to these topics. Compatibility of different clean-up methods with main types of coastline can be found in **Table 1**.

Table 1. Compatibility of various clean-up methods with main coastline types

CLEAN-UP METHODS **A** RECOMMENDED **B** SOMETIMES APPLICABLE **C** NOT RECOMMENDED **D** NOT APPLICABLE			TYPES OF COASTLINE							
			MAN-MADE STRUCTURES	**CLIFFS**	**BOULDERS**	**TIDAL POOLS AND SCATTERED ROCKS**	**COBBLES-PEBBLES-SHINGLE-GRAVEL**	**SANDY BEACHES**	**MUDDY COASTS**	**SALT MARSHES WITH VEGETATION**
REMOVAL	1.	MANUAL REMOVAL	B	B	B	A	A	B	B	B
	2.	MECHANICAL REMOVAL	B	D	D	D	A	A	C	C
	3.	USE OF VACUUM TRUCKS	B	D	D	B	B	B	B	B
	4.	USE OF BEACH CLEANERS	D	D	D	D	B	A	D	D
	5.	SAND-BLASTING	A	B	B	C	C	C	D	C
WASHING	6.	LOW PRESSURE FLUSHING (SEA WATER)	A	B	B	A	A	C	A	A
	7.	HIGH PRESSURE FLUSHING (SEA WATER)	A	A	B	B	B	C	C	C
	8.	STEAM CLEANING	A	B	B	C	B	C	C	C
	9.	BURNING	D	D	D	C	C	C	D	B
NATURAL DEGRADATION	10.	PUSHING OILED MATERIAL INTO SURF	D	D	B	D	B	C	C	D
	11	DISCOING (DISC PLOUGH OR HARROW)	D	D	D	D	B	B	C	C
	12.	LEAVE ALONE	B	B	B	B	B	B	A	A

3.1 Manual recovery of oiled material

This technique can be used on any type of coastline for collection of oil and oiled material, particularly if contamination is not too heavy. It is the only applicable method for clean-up of inaccessible beaches or ecologically very sensitive areas. Manual removal is a very selective clean-up method but at the same time very labour intensive and hence expensive.

Conditionally, this method also includes:

- collection of fluid oil with sorbents (with manual removal of saturated sorbents);
- manual scraping of oil from, for example, rocks, boulders;
- manual cutting of oil contaminated vegetation (to prevent re-contamination).

Equipment and material required:

- rakes;
- shovels / scoops;
- scrapers;
- brushes;
- buckets;
- heavy duty plastic bags;
- drums / barrels;
- protective clothing (gloves, boots, etc ...);
- food and drinks.

Technique

Oiled material is collected by manual labourers and piled (up to a maximum of 0.5 to 0.6 m). Piled material is then transferred into plastic bags, drums or barrels and transported for temporary storage and/or disposal.

The area to be cleaned up should be divided into several sectors. Workers should be grouped into small teams (5 to 10 men and a foreman) and each team allocated a sector to be cleaned in a given time (for example, day or half a day). Several such sectors should be supervised by a supervisor. Experience from past major accidents indicates an average collection rate of 1 to 2 m^3 of oiled material per person per day. This figure can be used as a guideline for planning the operation. If the clean-up rate is not adapted to the rate of removal (by trucks, boats, helicopters) of collected oily material, plastic bags or drums should be left above the high water line for removal later on. However, it has to be kept in mind that plastic bags that are left in strong sunlight for 1 to 2 weeks are likely to begin to deteriorate.

3.2 Mechanical removal of oiled material

Various earth-moving machinery (for example, graders, bulldozers, scrapers, front-end loaders) can be successfully used for oil and oily material removal from beaches (sand, gravel, pebbles, shingle). This method is less selective than manual removal (1 to 2% of oil in material collected by mechanical means as compared to 5 to 10% in manually collected material). Although it is faster than manual method, quantities of removed clean substrata are normally 3 to 4 times bigger. This method can be applied only on beaches that are accessible from land and have sufficient load bearing capacity. Mechanical removal can be combined with manual collection of oily material.

Equipment and material required:

- motor grader;
- elevating scraper;
- front-end loader;
- bulldozer;
- fuel.

Technique

Motor graders and bulldozers are used for removal of the upper, oil contaminated layer of the beach substrate. They work either parallel to the surf line from the clean side of the beach towards the water's edge (grader) or perpendicular to the surf line from the low tide line up the beach (bulldozer). Collected material is then picked up either by an elevating scraper or by a front-end loader and moved to a temporary storage area. Use of plastic sheets and rolls for lining of temporary storage pits will prevent leakage of oil. Machinery used for clean-up (including trucks) should not be operated over the contaminated area prior to cleaning in order to avoid burying of oil. Only absolutely necessary quantities of beach substrate should be removed. Removal of excessive amounts of sand or gravel, etc ... will result in erosion and deterioration of the beach. Erosion may be prevented by replacing removed substrate with clean material of approximately same sized particles.

3.3 Use of vacuum trucks

This method which has been used in most major oil spills consists of picking up liquid oil from pools in shoreline depressions or oil floating at the water's edge by means of vacuum trucks or honey wagons (vacuum tank trailers). Alternatively on tidal beaches trenches parallel to the water's edge or sumps can be dug, in order to concentrate oil prior to the use of vacuum trucks. If skimmers are not available, this method is the most convenient one for removal of floating oil.

Equipment and material required:

- vacuum trucks;
- honey wagons;
- hoses;
- protective clothing;
- fuel.

Technique

Vacuum trucks are backed up to the place where oil is concentrated and suction hoses are placed (manually) in the oil. Suction nozzles should be kept close to the surface in order to avoid picking up excessive quantities of water. Suction hoses should be of reinforced type with a diameter of 75 to 150 mm. Oil collection rate depends on various factors such as characteristics and quantity of oil, oil/water pick up ratio, distance to the temporary storage or disposal site, etc ... but 20 m^3 of oil per day per unit can be expected. Honey wagons, although of smaller capacity, have proved to be more cost efficient than large vacuum trucks (e.g. AMOCO CADIZ spill).

3.4 Use of beach cleaners

Beach cleaners are machines specially constructed for cleaning sand and gravel beaches from tar balls and hard oil lumps and patties. They are also used for clean-up of any other type of debris and litter. Beach cleaners can be either automotive units or towed behind a tractor. The most common working principle is the one in which a layer of contaminated sand is sifted through the wire mesh screen and returned to the beach, while tar balls and debris are dumped into a built-in or towed refuse container, although some other designs also exist.

Equipment and material required:

- beach cleaner;
- (tractor);
- (refuse container);
- fuel.

Technique

Automotive beach cleaners or tractors are operated at a slow speed (3 to 10 km/h). Cleaning should start from backshore edge of the contaminated beach. A path parallel to the water's edge is cleaned along the entire length of the beach and the beach cleaner is turned around to clean the next path parallel to and overlapping the first one.

3.5 Sand-blasting

This method is included in "removal" methods although it does not strictly belong among them. The use of sand-blasting equipment should be restricted to man-made structures requiring perfect cleaning. Occasionally, it can also be used on boulders or rocks that are not ecologically sensitive. Oil is removed by abrasive action of sand applied by sand-blasting equipment. The remaining oil, sand and surface material should be collected and transported to a disposal site.

Equipment and material required:

- sand-blasting unit;
- sand supply truck;
- sand;
- fuel.

Technique

Clean-up should start from the highest point of the contaminated structure and continue downwards. The remaining oil, sand and removed surface material can be removed either manually (shovels) or mechanically (front-end loader).

3.6 Low-pressure flushing

Flushing with low-pressure sea-water can be used to remove light, not too viscous oil from practically any type of coastline. It will not significantly disturb the substrate and hence it can even be used in very sensitive areas. Since oil removed by flushing can recontaminate another part of the shoreline, runoff should either be contained by booms or channeled to collection sumps and eventually recovered by skimmers, pumps or vacuum units.

Equipment and material required:

- pumps;
- hoses;
- recovery unit (skimmer, pump, vacuum truck);
- (boom);
- fuel.

Technique

Since direct flushing may either push oil deeper into the beach substrata or cause damage to flora and fauna, it is recommended to flood the beach substrate in order to float the oil off. If flushed oil is likely to enter the sea, booms should be properly moored near the shore around the working area. Flushing should begin at the highest contaminated point and continue towards the water's edge.

3.7 High-pressure flushing

Oil which has adhered to hard surfaces can be removed efficiently by cold or hot water under pressure. Commonly used pressures range between 80 to 140 bar, and if hot water is used, its temperature should be between 60° and 80° C. This method is applicable on rocky shores, boulders and man-made structures. Since released oil is likely to re-enter the sea and to contaminate another part of the shore, either booms and skimmers should be used to contain and recover it or sorbents should be applied at the base of the working area. Operators working with high-pressure water jets should be properly trained since unskilled workers can destroy complete existing flora and fauna (e.g. shellfish) and even damage man-made structures.

Equipment and material required:

- high-pressure unit (self-contained, with heater);
- high-pressure hoses;
- hand lances;
- plastic sheets;
- booms;
- recovery units / vacuum trucks / pumps;
- sorbents;
- protective clothing;
- fuel.

Technique

High-pressure water flushing should begin at the top of the surface which has to be cleaned and proceed downwards to its base. Adjacent surfaces should be protected from contamination by plastic sheets which will also direct oil and water mixture to the collection point. Berms or trenches can be constructed to channel the flow towards these collection sumps. Oil removed from the contaminated surface can be recovered by skimmers, vacuum units or pumps. It is recommended to time the start of the clean-up operation in such a way that the base of the surface to be cleaned is reached at low tide.

3.8 Steam cleaning

Very viscous, weathered oils can be removed from rocks, boulders or man-made structures by using steam. By raising the temperature of oil, steam will lower its viscosity and hence enable it to flow. Since the application of this method will most probably destroy any living organism existing on the contaminated surface, it should be used only if it is absolutely necessary to remove the oil and after assessing possible consequences for the environment. Practically it should be used only on man-made structures.

Equipment and material required:

- steam cleaner (fed with fresh water);
- hand lances;
- plastic sheets;
- booms;
- skimmers / pumps / vacuum units;
- fresh water;
- fuel;
- protective clothing.

Technique

Virtually the same as high-pressure water flushing. Special attention should be paid to strict application of safety measures while working with steam (150 to 160 °C, 20 bar).

3.9 Burning

Although burning appears to be a logical solution for removal of oil from contaminated shores, this method is very rarely applied. Besides being detrimental to flora and fauna living in the polluted area, it is not possible to burn the oil completely because of the cooling effect of beach substrata. Incomplete burning results in heavy air pollution and oily soot is most likely to contaminate adjacent environs. Addition of oxidizing agents or sorbent "wicks" may improve the combustion but until now complete destruction of oil has not been achieved through this method. 'In situ' burning of oiled material is considered rather as a disposal method than as a clean-up method.

Controlled burning of dry oil-coated plants at the end of the vegetation period (autumn, winter) in salt marshes can be regarded as the only effective application of this method.

Equipment and material required:

- (flame thrower);
- fire fighting equipment;
- (burning agents : diesel fuel, gasoline, chemical products);
- protective clothing.

Technique

In order to ensure controlled burning, a plan should be carefully drawn up and, if necessary, fire breaks provided for. The fire should always be started on the **upwind** side of the contaminated area. Flame throwers or burning agents may be necessary to ignite the fire. The fire may either be left to burn until exhausted or until it reaches a barrier.

Safety regulations should be strictly observed and it is imperative that fire fighting equipment is kept on stand-by. Personnel engaged in the operation should always remain upwind of the fire.

3.10 Pushing oiled material into surf

This technique can be used for the cleaning of not too heavily contaminated cobble, pebble and gravel beaches as well as for boulders. It can be particularly efficient if applied before or during the winter season when storms and heavy seas are expected. The contaminated layer of beach material is pushed into surf where wave action and movement of material will clean the oil. Material that is pushed into the sea will be returned to the beach by natural wave and tidal movements. Cleaning of boulders by this method will result in the change of beach shape and character.

Equipment and material required:

- bulldozers;
- fuel.

Technique

A bulldozer is operated perpendicular to the surf line starting from the upper end of the beach. Only the contaminated layer of beach substrate is pushed into the intertidal area. The bulldozer is returned along the cleaned path and repositioned in such a way that a second path is cut parallel to and overlapping the first one.

3.11 Discing into substrate

If a lightly contaminated sandy or gravel beach has no recreational value, oil can be left to degrade naturally. This method does not remove oil from the beach but only increases the rate of natural degradation. A disc-plough, towed by a tractor, is used to achieve an even mixing of the contaminated top layer of sand or gravel with clean beach substrata under it. The technique can be applied only on beaches with sufficient load bearing capacity to be trafficable for heavy machinery.

Equipment and material required:

- tractor (tracked);
- disc-plough;
- fuel.

Technique

A tractor is operated alongside the entire length of the beach, parallel to the water's edge, starting from the backshore edge of the contaminated area. The next path should be parallel to the first one and slightly overlapping it.

3.12 Leave alone

In certain cases, the only possibility to deal with stranded oil will be to leave it to degrade naturally, that is, to do nothing. "Leave Alone" method can either be justified by very high ecological sensitivity of the contaminated area in which application of any other clean-up method would cause more damage than oil itself or by the fact that the contaminated area has no commercial importance at all. Sometimes oil will have to be left to degrade naturally if the contaminated area is not accessible either by land or by sea.

This method can also be considered in high energy beaches before or during the winter season when it is almost sure that wave and tidal action will remove stranded oil before the start of, for example, touristic season.

Technique

Stranded oil is left on the beach. Periodical monitoring is suggested in order to control the rate of natural degradation of the oil.

4. REMARKS ON DIFFERENT TYPES OF COASTLINE

Since each type of coastline has its own characteristics, brief notes on clean-up methods applicable on main types are mentioned below:

4.1 Man-made structures

Normally environmentally non-sensitive and accordingly any suitable method can be applied. Low and high-pressure flushing, steam cleaning and sand-blasting will give the best results. Use of dispersants can be acceptable, but their effectiveness has to be checked before treatment.

4.2 Rocky shores, cliffs

Clean-up should be considered only if necessary. High and low pressure flushing of oil can give good results, but if more severe methods are used, attention should be paid to avoid excessive abrasion of rocks. Manual cleaning of vertical rocks presents a hazard to the personnel involved and hence strict safety measures have to be applied.

4.3 Boulders

Manual cleaning and flushing are recommended if cleaning is required but results will generally be poor. If flushing is selected as clean-up method, only sea water should be used. Boulders can be removed by heavy machinery but it will almost surely result in changing the character of the beach.

4.4 Tidal pools with scattered rocks

This is one of the most difficult types of shoreline to clean, but if oil is not removed, it can recontaminate other areas for long periods. Use of sorbents gives good results as well as manual clean-up and flushing. Sea-water should be used for the latter method. Use of booms and skimmers will be necessary to prevent recontamination of adjacent areas.

4.5 Cobbles, pebbles, shingle, gravel

These beaches are difficult to clean but clean-up is usually indispensable because of their recreational value. Both mechanical and manual methods of oiled-material removal are most commonly used, but flushing with sea water can also give good results if the oil is not too viscous. All methods of natural clean-up can also be applied. If the beach is polluted before the season of storms and big waves, "leave alone" action or pushing beach substrate into intertidal zone may give very good results. If heavy machinery is used for clean-up, the bearing capacity of the beach must be checked prior to its arrival. Immobilization of machinery and/or vehicles used to transport the collected material may create serious problems if this is not done. Use of booms and skimmers to prevent recontamination of other beaches is indispensable if flushing is selected as the clean-up method.

4.6 Sand

Besides their usual amenity use and hence commercial value, sandy beaches are not environmentally very sensitive. If sand particles are fine, only a thin top layer of beach will be contaminated, but even in coarse sand, oil will not penetrate too deep. Mechanical and manual removal of oiled sand are the most recommendable clean-up methods. Machinery should not be operated over the contaminated beach in order to avoid burying of oil. Only absolutely necessary quantities of oiled sand should be removed. If a large quantity of sand is removed, it can be replaced by the clean sand of the same sized particles. Replacement of removed sand by coarser or finer substrate can result in deterioration of the beach.

4.7 Muddy coasts

They should be cleaned only if it is environmentally justifiable. Flushing the oil with low-pressure water is recommended provided that flushed oil is then contained and recovered. Skimmers and vacuum units can be used for this purpose. Use of heavy machinery is not recommended since it will bury the oil that normally remains on the surface. Use of sorbents may render good results too. Very often the best solution is to leave the oil to degrade naturally.

4.8 Salt marshes with vegetation

These are environmentally the most sensitive type of coastline. Virtually any attempt to clean up the salt marsh will do more harm to the system than the oil itself. If possible, priority should be given to protection of salt marshes by booms. However ecologists should be consulted prior to taking any action. Collection of oil with sorbents (organic) combined with manual recovery is one possible clean up method, but even this can disturb the salt marsh environment.

5. THE USE OF DISPERSANTS ON SHORE

The use of dispersants in shore clean-up operations is a very controversial issues. Environmental effects of dispersants use are often considered to be more harmful than the effects of the oil itself. If national regulations regarding the use of dispersants on shore do not exist, application of dispersants should start only after consulting the local authorities or scientists familiar with the local marine and coastal environment. If however, a decision to use dispersants on shore has been taken, the following considerations should always be borne in mind:

- Dispersants should not be used in the sensitive marine environments such as salt marshes, estuaries, coral reefs, lagoons, etc ...
- Use of dispersants is useless on high energy shores such as exposed cobble, pebble or gravel beaches, exposed rocky shores, etc ...
- Only types of oil which may undoubtedly be removed by dispersants should be treated, i.e., **effectiveness of dispersants should be tested prior to their application**.
- Dispersants should **only be used for an additional clean-up**, after the removal of massive quantities of oil by other available methods.

- Dispersants may be used on sand, gravel and pebble beaches and sheltered rocky shores needing extensive clean-up.

- Dispersants can be used on man-made structures, but not too close to the water intakes of power plants, refineries or desalination plants to avoid dispersed oil entering into their systems.

- Both hydrocarbon solvent dispersants (2nd generation), and concentrates (3rd generation) diluted with sea water may be used.

- Dispersants can either be sprayed manually using "backpacks" or by specialized beach spraying vehicles. On inaccessible beaches, use of aircraft may be considered. Dispersants can either be used just before the rising tide or their application should be followed by flushing with large quantities of sea water.

- Dispersants can also be applied with brushes, and then hosed with water (particularly useful on man-made structures, boulders and rocks).

- Sometimes, the application of dispersants will not result in dispersion of oil but only in its removal from the beach material. In such a case, removed oil should be contained by a boom and recovered by a skimmer.

6. THE USE OF CLEANING AGENTS

At later stages of response (e.g. restoration phase), oil is often solidified and even the use of high-pressure hot water is not sufficient to soften and detach it. Cleaning of contaminated surfaces (quays, walls, rocks) can be in such cases facilitated by the use of specially developed products. Nevertheless, the use of cleaning agents does not exclude either pressurized hot water washing or recovering removed oil, since the oil which drains into the sea tends to resurface rapidly.

The use of cleaning agents becomes a necessity after approximately a month of weathering of oil on the rocks.

The most efficient products are those containing some petroleum fractions: among these, there are some which have toxicity low enough to render their use on shore possible.

The best results are obtained by spraying cleaning agents onto the polluted surface 15 to 30 minutes prior to washing. Cleaning agent volume to pollutant volume ratio should be 1 to 3. Prolonged contact times favour the action of the cleaning agent, but these should not exceed 2 to 3 hours because of the risk of solvent evaporation.

Certain products tend to emulsify detached oil and accordingly they seem to favour dispersion. In fact this dispersion is only partial and short-lived. Use of this type of product should be limited to those exceptional cases when recovery is not possible.

Chapter 12

STORAGE , TREATMENT AND DISPOSAL OF COLLECTION OILED MATERIAL

1. INTRODUCTION

Temporary storage and final disposal of oil and oiled material collected during an oil spill accident are two issues which are often neglected in the planning of oil combating operations. Unfortunately such an attitude may easily hamper the entire operation. A vast quantity of oil and oily debris can result from a major oil spill and careful planning is needed in order to provide for its disposal. There is a number of disposal techniques and the selection of the most adequate one will depend on many factors, some of which can be determined and elaborated in advance. These should normally be entered into the Contingency Plan (local, national) so that in case of an accident, only variable parameters need to be considered prior to the selection of the most appropriate disposal technique. Parameters which can be determined in advance include:

- possibility and most suitable methods for temporary storage of oil and oily debris near envisaged places of collection;
- existence and capacities of refineries, thermic power plants, cement works or other suitable industrial installations which can possibly re-use collected oil, including the specifications of oily materials they can use;
- potential dumping sites (locations, geological characteristics, capacities);
- waste land which can be used for farming of oil (location, surface, capacity, cost);
- distances and most suitable traffic routes between envisaged places of oil collection (including harbours in case of off- shore oil recovery) and potential storage and disposal sites;
- manpower and logistic requirements for each of envisaged disposal methods - cost effectiveness.

If the above mentioned data are elaborated in the Contingency Plan, the only parameters which will have to be determined in case of an accident will be:

- quantity of material to be disposed of;
- characteristics of collected material, e.g. type of oil, oil to water (sand, debris) ratio, etc...

Since the final disposal of oil is usually very expensive, it is also indispensable to define who is the owner of the collected oil prior to the start of the operation. This may help to clarify various financial problems to which final disposal of oil can give rise to later on.

2. TRANSPORT OF OIL AND OILED MATERIAL

Transport of oil and oiled material resulting from an oil spill may present a major logistic problem. Means of transportation will include sea-going vessels and land vehicles. In certain cases, even helicopters can be utilised for this purpose. Whatever means of transportation used, these should be equipped with some kind of leak-proof container(s) which will prevent contamination of non-polluted areas.

Liquid oil collected during an offshore oil spill recovery operation can be stored and transported in:

- built-in tanks on board (recovery) vessels;
- towed, flexible floating tanks;
- barges (self-propelled or towed).

If the viscosity of spilled oil allows its recovery, it would usually also be possible to pump this oil into any of the above mentioned containers. However, once filled these may become very difficult or even impossible to empty because of an increase in viscosity of oil due to (water-in-oil) emulsion formation by pumps, settling of water which might have been used as vector for pumping, change of temperature, or turbulence caused by sea movement. In order to avoid these problems, addition of emulsion- breaking chemicals to recovered oil whilst filling the tanks, is recommended unless tanks are provided with heating coils. Before taking a decision on its final disposal, the oil can either be left in these tanks or transferred to shore storage facilities by road tank lorries and rail tank cars. In addition to tank lorries and tank cars, vacuum trucks, vacuum tank trailers and flat bed lorries equipped with tanks or drums can also be used for land transportation of liquids to disposal sites.

Semi solid or solid oiled material (including high viscosity oils and emulsions) should be transported in open top containers or skips, as well as in dump trucks. Should there be a risk of oil leakage, containers ought to be lined with heavy duty, sealed plastic or rubber sheeting.

3. TEMPORARY STORAGE

In a great majority of oil spill accidents, the rate of oil recovery (offshore and onshore) will be higher than the rate of its final disposal, even in those cases when the methods and means for it have been studies and outlined in advance (in the Contingency Plan). Such a situation necessitates provision of temporary storage capacities, preferably as close as possible to the site where oil is being recovered. Several options can be considered:

- **Improvised pits:** If local conditions permit, one of the most simple ways to provide temporary storage for collected oiled material is to dig pits in the ground. Experience of past spills suggests that the most convenient pits are long (approximately 10 m, narrow 2 to 3 m and not too deep 1.5 to 2>m). To prevent leakage of oil and possible contamination of the underground water table, pits should be lined with heavy gauge plastic (polyethylene, PVC) or oil-resistant rubber sheeting. Before lining the pit with oil-proof material, it may be useful to line it with a layer of sand or felt in order to avoid possible puncturing of the plastic material by stones. Collected oiled material is dumped into these pits and left for further treatment and/or transportation to the final disposal site.

In case of expected rainfall, pits should not be entirely filled with oily waste so as to prevent possible overflowing caused by rain. Following the removal of stored material the land used for temporary storage should be restored to its original state.

Alternatively earth walls can be constructed (1 to 1.5 m) to form rectangular reservoirs above the ground, which should also be lined to prevent leaching of oil. In such a case, attention should be paid to ensure that vehicles used for transporting the oiled material, do not damage the earth walls.

- **Open top oil drums:** Usually available in large quantities, these drums can be used for temporary storage of any kind of collected oil and oiled material. Since they are also suitable for transportation, oil drums can be particularly useful for handling of very viscous oils and emulsions. To avoid contamination of land utilised for storage of oil in open top drums, plastic or oil-resistant rubber sheeting can be used.

- **Heavy duty plastic bags:** The most suitable way of storage and transportation of oiled material collected manually from beaches. The site on which filled plastic bags are to be stored prior to their transportation to final disposal should be protected with plastic or rubber sheeting.

  CAUTION: If plastic bags are left in strong sunlight for 1 to 2 weeks, they may start deteriorating and consequently release collected oily material. Another inconvenience of using plastic bags is the problem of their emptying at the final disposal site.

- **Flexible tanks:** If available, open top flexible tanks, with or without support, and pillow tanks can be used for temporary storage of liquid oil, particularly at the beginning of clean-up operations. They are not suitable for solid oiled material (pebbles, shingle, debris).

- **Fixed storage capacities:** If storage tanks of refineries, oil terminals, deballasting stations, etc ... exist in the vicinity of the site of oil spill clean-up activities, they may be used for temporary storage of liquid oils. Necessary arrangements with owners or operators of these installations should be made prior to an oil spill accident (Contingency Plan!) to determine available capacities and types of oil which can be temporarily stored in this way.

4. SEPERATION OF OIL

Oil collected during the spill response operations inevitably contains a certain amount of sea water and/or solid materials. The purest is the oil collected by skimmers from the sea surface (up to 90% of oil), while beach material collected during the shore clean- up may contain only 1 to 2% of oil. Oil contents of various emulsions and different types of oiled material vary between these two figures. The separation of oil from other substances (water, sand, gravel, wood, plastic, sorbents, etc), which had been collected together with it, is done in order to:

- recover as much oil as possible for re-use,
- reduce the volume of material which has to be handled, transported and stored,
- facilitate the final disposal,

The following separation methods are most frequently used:

4.1 Gravity Separation

Mixtures of oil and water can be separated making use of differences in their respective densities. Oil which is lighter than water, tends to rise to the surface and water settles at the bottom of the settling tank. Water is successively removed from the bottom of the tank and oil free of water is pumped (skimmed) from the top. Gravity separation can be carried out in purposely built settling tanks (API separators, circular clarifiers, corrugated plate separators, etc ...), flexible or movable open top tanks, skips, storage tanks on board vessels and even in open top oil drums. Strict observation of regulations concerning effluent (water) quality is not necessary in oil spill situations since it is not likely that water from separation processes may have any significant detrimental effects on a marine environment already affected by a spill.

Stable water-in-oil emulsions can also be separated by this method provided that chemical additives (emulsion breakers or demulsifiers) are thoroughly mixed with the emulsion which is treated. Best results are obtained if emulsion breakers (0.1 to 0.5% of the total volume) are injected into the suction side of the transfer pump which thus ensures excellent mixing of chemical and emulsion. Alternatively, static mixers can also be used.

If the available settling tanks are provided with heating coils, heating an be used to beak unstable emulsions. Recommended temperature is around 60 °C. A combination of heating and adding emulsion breakers (approximately 0.1%) can render very good results.

4.2 Removal of Debris

If otherwise, relatively clean oil contains pieces of debris (sea-weed, pieces of wood, plastic, etc....) these can be removed by straining the oil through a wire mesh screen. This operation can be followed by gravity separation (in deballasting station, for example).

4.3 Collection of Leaking Oil

The simplest method which can be applied in order to separate liquid oil from oiled material (sand, pebbles, gravel, debris) is to collect the oil draining from temporary stored beach material. Such oil can be channelled into collection sumps and therefrom pumped into suitable tanks.

4.4 Washing

Cold water washing of oiled material collected during beach clean-up operations, may release oil which has adhered to solid material (cobbles, pebbles). Washing can be carried out in temporary storage pits which should, for this purpose, be rather shallow and of a larger surface. Resulting oil and water mixture is then transferred to settling tank(s) for gravity separation.

4.5 Extraction

Theoretically, oil can be recovered from oiled beach material by applying solvent extraction. However, this method needs to be further developed.

4.6 Sieving

If oil is in the form of solid lumps or tar balls, it can easily be separated from sand either by manual or mechanical sieving.

5. FINAL DISPOSAL METHODS

Three groups of methods can be used for the final disposal of oil and oiled material resulting from an oil spill:

- Recovery of oil for re-use.
- Stabilization of oil and oiled material.
- Destruction of oil.

Obviously, the first priority should be given, if possible, to those methods which enable the re-use of collected oil and only if this is not feasible, should stabilization of oiled material or destruction of oil be considered.

5.1 Re-use of Oil

If oils collected during an oil spill clean-up operation are suitable for reprocessing and re-use, the total cost of the operation can be significantly reduced. Potential users of such oils are: refineries, waste oil recycling plants, power plants and cement works.

Specifications of oils which each of these plants may use should be indicated in the Contingency Plan and these specifications normally cover water, solids and salts content as well as viscosity of the oil. Oil which meets the necessary requirements can either be blended with fuel oil for internal use in the plant or in the case of crude oils, blended with feedstock for refining.

5.2 Stabilization of Oiled Material with Binding Agents

Large quantities of oiled material can be stabilized by mixing it with binding agents and then using it for e.g. road construction. The most commonly used binding agent is quicklime although certain commercial products are also available (usually they are more expensive and equally or even less efficient than quicklime). This method is particularly effective for the treatment of oiled sand. 5 to 20% of quicklime (exact ratio should be determined experimentally), is mixed with the oiled material either in mixing plants or by layering technique. Mixing units can be mobile or fixed, and they will basically comprise: a loading hopper, a sack opener, continuous weighing of waste, a mixer and a discharge hopper. Such an installation constructed in Brest (France) for the treatment of AMOCO CADIZ oily waste had a capacity of up to 1000 tons/day.

Layering technique consists in spreading oiled material (0.2 to 0.3>m) on the flat surface and mixing it with quicklime using a "pulverizing mixer".

Alternatively pulverized flue ash from coal fired power plants can be used instead of quicklime, particularly in "layering technique".

Construction material resulting from stabilization process is clean and stable, does not release oil and can easily be stored and transported. This method can be particularly suited for those Mediterranean areas in which quicklime is readily available in sufficient quantities.

CAUTIONS:

1. The process is exothermic and if the exact ratio oil/quicklime has not been determined for a specific waste, the mixing may generate **excessive heat** and cause a violent reaction (fire/explosion).

2. The process of mixing oiled material with quicklime inevitably generates a large quantity of **corrosive dust**. Consequently, it should be carried out in uninhabited areas and operators should wear protective clothing and face masks.

Although not strictly a "stabilization method", covering dust and gravel roads by oiled material can sometimes also be considered as a disposal method. Before applying this technique it is necessary to verify that there is no possibility of ground water contamination by leaching oil.

5.3 Land Farming of Oil and Oily Debris

This oily waste disposal method is based upon the well known fact that certain micro-organisms can oxidize hydrocarbons, hence causing the natural biodegradation of oil. It can be particularly efficient in the Mediterranean region since the rate of degradation depends on ambient temperatures and in this region these are likely to be sufficiently high around the year. The main requirement is a relatively large area of low value land (Contingency Plan!). The permeability of the substrata should be low to prevent possible contamination of water table. The only equipment required is common agricultural machinery. (If necessary, pH value of the soil can be adjusted to a value higher than 6.5 with lime).

The selected piece of flat, low value land, is first harrowed and then runoff diversion channels constructed off it. Runoff caused by rainfall can be channelled to a catchment pool. A layer of oil and/or oiled material 0.02 to 0.2 m thick is then evenly spread over the surface. The oil is left to weather. When it is no longer wet and sticky, it is mixed with soil by using a plough, a disc plough or a rotavator. During the first six months the substrate should be mixed once monthly in order to increase the aeration, but later on this can be done less frequently. Complete degradation of oil treated by this method can be expected in one to three years period. The rate of biodegradation can be increased by adding fertilizers, for example, urea and ammonium phosphate. Typical doses are 10 parts of nitrogen and 1 part of phosphorus per 100 parts of oil.

Following the degradation of oil, the land can be used to cultivate almost any kind of plants including grass, decorative plants and trees. If crops are grown on land previously used for aerobic decomposition of oil, these should be monitored for possible heavy metals content.

5.4 Composting

Another way to degrade the oiled material biologically is composting, that is, biological conversion of oily waste into stable, humic material. Composting can either be achieved by adding the oily waste to domestic refuse or by heaping of natural sorbents (e.g. straw, wood shavings, peat) saturated with oil.

If mixing with domestic refuse is used, only small quantities of oiled material should be spread over the layer of refuse (1 to 2% of the total weight of refuse) and covered with another thick layer of domestic refuse. Since the bacterial decomposition of oil is an exothermic process, the heat developed in the mixture will result in a decrease of oil viscosity and hence its leaching. If quantities of oiled material added to domestic refuse are too big, most of the oil will leach and accordingly it will not be transformed.

Another technique consists in mixing oiled material with domestic waste and depositing this mixture in shallow pits sealed with a layer of clay. The deposited mixture is covered with soil and left like this for several months, resulting in an inert, cake-like residue.

If natural sorbents are used for oil recovery, they can be stacked into heaps in order to facilitate composting. The resulting material is a dry, compost-like residue.

Both described methods are suitable for treatment of only limited quantities of oiled material: the former because of a low percentage of oiled material which can be successfully composted and/or because of (usually) limited quantity of available domestic refuse and the latter by normally limited use of sorbents in clean-up operations.

5.5 Landfilling

Dumping of oiled material is often the first reaction to the disposal problem although this method should be applied only if there is no possibility to apply any of the previously described ones. Direct dumping of oiled material should be carefully planned. The selected landfilling site should be checked beforehand for imperviousness to avoid possible contamination of underground waters with hydrocarbons. Waste to be disposed of by landfilling should have less than 20% of oil. Spreading of oiled waste above ground level should be given priority over filling of holes and/or depressions. Substrata near the landfilling site should be analysed periodically to determine any possible leakage of hydrocarbons.

Oiled material can also be dumped in municipal waste disposal sites. Domestic refuse is likely to absorb disposed oil thus preventing its further leaching. However the layer of oily material should be thin (10 cm) and it should be covered by 1 to 2 m of domestic refuse to prevent re-surfacing of oil.

5.6 Burning

The direct burning of collected oily waste is rarely feasible. Incomplete burning, air pollution and disposal problems of tarry residues are some of the drawbacks of this method. However if tests prove that it is possible to burn collected oily debris, this technique can be applied particularly in remote places. Before the start an operational plan should be drawn up and, if necessary, fire breaks provided for. The fire should always be started on the **upwind** side of the burning site. Flame throwers or burning agents may be required to ignite the fire.

Safety regulations should be strictly observed and it is imperative that fire fighting equipment is kept on stand-by. Personnel engaged in the operation should always remain upwind of the fire.

5.7 Incineration

Different types of portable incinerators have been developed for high temperature incineration of oiled material. The rotary kiln type is particularly useful for incineration of oil with high (up to 80%) solid contents. Products resulting from incineration are environmentally acceptable gases and clean, inert solids (gravel, sand, etc ...). Addition of fuel is regularly required due to the low calorific value of treated material. High cost of the equipment and additional costs for fuel are the main drawbacks of this method.

Domestic waste incinerators are usually not suitable for incineration of oily debris because of its high salt contents (corrosion caused by chlorides).

Industrial waste incinerators are usually designed for strictly and precisely defined quantities of material and can hardly deal with amounts of oiled material resulting from an oil spill.

For small quantities of oily debris, a simple "incinerator" can be constructed from an open top oil drum. Air is supplied by a compressor or a fan blower through a steel pipe of 3 to 5 cm in diameter, welded tangentially near the drum top. The bottom of the drum can be replaced by a grating to enable a continuous removal of burnt residues. The "incinerator" is filled manually from the top.

Chapter 13

STORAGE AND MAINTENANCE OF EQUIPMENT AND PRODUCTS

1. INTRODUCTION

Equipment used in the spill response operations and, in particular, in shore clean-up operations belongs generally to two main categories:

1) specifically designed oil spill response equipment;

2) non-specific equipment (used normally in e.g. agriculture, road construction, transport, communal services, etc.).

While the second category is likely to be provided (hired or requisitioned) by subcontractors who operate such equipment on a daily basis, and accordingly have established maintenance routines, specialised oil spill response equipment might come either from national (district, local) stockpiles or from the stockpiles of clean-up contractors.

Companies specialized in oil clean-up activities do not depend exclusively on oil spills for generating their income: they are usually engaged on a regular basis in similar activities (oily waste disposal, cleaning of oil leaks from plants, oil pipelines maintenance, oily residues collection and treatment, collection of flotsam from ports, etc...) required by e.g oil refineries, power plants, tank farms, repair shipyards, ports and other industries located on or near the shore. In order to be able to carry out efficiently their daily work, such companies necessarily keep their equipment in good working order and carry out regular inspections and maintenance work.

On the other hand, state-owned equipment, purchased and stored for use exclusively in cases of emergency, is subject to a very irregular working regime, i.e. long periods of rest are infrequently interrupted by relatively short periods of very intensive use. This puts an enormous stress on such equipment once it is deployed in a spill response operation. If such equipment is not regularly inspected, tested and, as necessary, maintained during these long periods of inactivity, it is very likely that the equipment will not be able to endure all exigencies of an intensive spill clean-up operation.

The maintenance of equipment and checking, testing and replenishment, as necessary, of various products and materials will, according to circumstances, be the responsibility of:

- either the Department which has ordered the material and continues to take care of it, or of this Department's sub-contractor;

- the Authority which has been put in charge of the use of equipment or products.

In both cases, it is advisable to appoint an **officer in charge of maintenance**, who should also be responsible for keeping updated the servicing documentation and, if necessary, its translation.

2. STORAGE

As far as possible, equipment should be stored in a dry, properly ventilated place. In order to increase the life span of the material, humidity and temperature must be controlled and exposure to UV rays avoided. In addition, material should be protected against pests. Floating booms which are stored folded or rolled up should be unfolded and unrolled regularly in order to prevent sticking of the material and forming permanent creases which would weaken the material.

Warehouses should comprise an empty space (surface) where equipment can be cleaned up from oil and sea water and where certain maintenance work can be carried out. It is essential that the equipment is easily accessible in order to enable both inspection and maintenance. Access of vehicles and lifting gear needed for rapid deployment of equipment and products in case of emergency should also be ensured at all times. Security measures should be provided for, in order to prevent acts of vandalism or thefts.

Skimmers and their power packs should be protected from damage and damp salty atmospheres causing corrosion. Oleophilic mops, rubber belts, and plastic material incorporated in skimmers will perish if exposed to direct sunlight for prolonged periods. Skimmers should therefore be stored in properly ventilated, covered sheds or warehouses.

2.1 Storage and aging of dispersants

2.1.1 <u>Storage</u>

Quantity of dispersants to be stored for emergency response needs to be assessed during the preparation of contingency plans. It will be calculated on the basis of the quantity needed to respond to the most likely size of spill during the period necessary to bring in replacement stocks. The time needed for stock replenishment (either by the manufacturers or from other sources) has also to be negotiated and determined in advance (cf. Chapter 9). Arrival of new quantities of dispersants more than 48 hours after the start of spillage will be useless in most cases.

Dispersants are most often stored in 200 litre **steel drums**, usually in open space or preferably in sheds. Although the possibility that the drums will corrode from the inside should not be neglected, it is more likely that the corrosion will start from the outside. It is therefore recommended to store dispersants in metal drums protected internally and externally. If possible, drums should not be exposed to rain, and regular control of stored drums is strongly recommended.

Alternatively, dispersants may be sold and stored in **plastic drums**, which are corrosion resistant. Use of plastic drums has given rise to other problems: plastic materials age badly in the open air and drums should therefore be protected from direct sunlight in order to avoid their deterioration. On the other hand, drums that are placed at the bottom of the pile deform and may finally collapse under the weight of the upper drums, and they should be stored on some kind of shelves.

Delivery and storage of dispersants in **bulk containers** is also possible. From the operational point of view, taking into account the need for quick response and hence the need for transporting large quantities of the product, this option is preferred to storage in drums. Storage in **road tank trailers** is even more practical.

Countries who make use of specialized anti-pollution vessels may opt for storage in **vessels' integral tanks**. For spraying from other vessels, when the need arises, dispersants can be transferred from storage containers to flexible pillow tanks, which can be placed on board practically any vessel.

Relatively high capacity portable pumps, made out of materials resistant to the components of dispersants, need to be available for the transfer of products from storage containers to spraying units.

2.1.2 <u>Aging</u>

Dispersants are complex mixtures of various components, and with aging, their properties may be subject to changes, i.e. their stability is not necessarily good. During the prolonged storage, certain components may separate from the solution in layers or even crystallize.

These processes are still not clearly understood. However, it is certain that they may lead to reversible or irreversible deterioration of the original properties of the product. Most often, this deterioration is reflected as a loss of effectiveness of the product.

In the most simple case, the effectiveness can be restored by mixing the contents of the containers in which the dispersant is stored. If one of the components has lost its activity, the manufacturer might be able to reactivate the product by adding additional active components. In the worst case, the product cannot be recuperated and it therefore has to be disposed of, destroyed or used for another purpose (e.g. as a solvent).

Countries which have established approval or acceptance procedures regularly require the information on shelf-life from the manufacturer of the product (cf. Chapter 6, paragraph 6.6). Regardless of the manufacturer's declaration, the most reliable method for discovering changes in the original quality of the stored dispersant is to periodically test its effectiveness and to compare the results with the results obtained using the same method and the same product when it was fresh. Such tests can be easily carried out and do not necessitate expensive laboratory equipment.

3. INSPECTION AND TESTING

The best way to ensure the equipment's good working order is to test it periodically during basic trials, drills or exercises. At the same time, these exercises (trials) should be used to train personnel designated to operate this equipment in case of an accident. They should serve as the first level of training of oil spill responders, which should be carried out on the initiative of maintenance officers in each Department, and should concern only the use of equipment owned/managed by that Department. The following table indicates reasonable regular intervals for testing different categories of equipment, but it can also help the maintenance officers to plan regular training of operational teams.

EQUIPMENT	INTERVAL	TEST
Oil pumping units	monthly every 6 months	. simple starting . handling training/instruction
Mechanical recovery devices	Every 6 months	. operational trials (without pollutant)
Booms	Every 6 months	. deployment of a considerable length (at least 3 sections) . unfolding the entire length
Skimming barriers	Once a year	. operational trials/instruction
Floating, flexible and rigid barges and storage capacities for collected oil	Once a year	. inflation of inflatable units . mounting/erecting other units . filling with water
Spraying equipment for . dispersants . loose sorbents	Once a year	. instruction session for personnel responsible for handling
Storage capacities for treatment products	Once a year	. checking storage conditions . agitation of drums . oldest products in stock may be used for trials

NOTE: Whenever the equipment used in trials/exercises was in contact with sea water, it is strongly recommended to rinse it with fresh water prior to storing it again.

4. MAINTENANCE DURING RESPONSE OPERATIONS

During spill response operations there will be a need for two different types of maintenance related activities: **preventive maintenance** and **repair of breakdowns**.

It goes without saying that well organised and efficient preventive maintenance should help keeping the need for repair of breakdowns, as low as possible. It is also important to note that the proper use of equipment, observing established rules of good housekeeping, under conditions recommended by the manufacturer and without exceeding the limits of the material resistance, will drastically reduce the need for emergency repairs during spill clean-up. Finally, only properly trained operators will be able to use the equipment correctly, thus reducing the chance of equipment being unnecessarily damaged.

In case of an oil spill, maintenance facilities should, if possible, be established not to far form the spill (clean-up) site. The maintenance officer (or supervisor) should ensure the presence of specialized manpower (1-2 mechanics, a fitter, 1-2 electricians, possibly a plumber and a carpenter) and of required materials, tools and spare parts. He should also be responsible for ensuring sufficient supplies of fuel and lubricants for vehicles, boats and different machinery used in clean-up operations. In order to ensure smooth progress of spill response activities during the hours of daylight, inspections of equipment should be carried out at night, using floodlighting.

A great deal of spill response equipment, and **skimmers** in particular, has been designed to use hydraulic power for its operation, although pneumatic powered equipment is also not uncommon. Other types of power are less used in specialized antipollution equipment. Hydraulic power is very well adapted to difficult working conditions, it is safe, reliable and allows for a good transmission of energy required for running the specialized equipment.

Regular checking of tightness of hydraulic circuits will ensure efficient operation of the equipment, while a good supply of couplings required for various envisaged uses will enable the multiple use of each hydraulic power-pack.

Most **boom** manufacturers provide emergency repair kits and these should always be available during clean-up activities, in order to enable prompt repair of sometimes minor damages which could, if not mended, make a shorter or longer section or length of boom unusable.

If **dispersants** (which are strong digressing agents) are used in clean-up operations, particular attention should be paid to checking that lubricants in various pieces of equipment are not contaminated with dispersants. This refers in particular to tail motor assembly of helicopters. Dispersants also attack exposed rubber components and various paint coatings. They may cause slight crazing of stressed Perspex used in windscreens and windows of vessels and aircraft. Thorough hosing of all vessels, aircraft and other machinery exposed to dispersant spray is therefore necessary if potential damage to the equipment is to be prevented.

5. EQUIPMENT WASHING, CLEANING AND DECONTAMINATION

Equipment used in spill clean-up operations should be regularly (daily, if possible) cleaned and inspected in order to rectify any wear or damage. This applies, in particular, to booms and skimmers, but also to other mechanical devices and various hand tools and personal protective clothing.

A **washing facility** should be set up at the beginning of a clean-up activities and operated until the terminations of operations. The following are the main points to be considered when setting up a washing facility:

- designate an area for washing, taking into considerations the accessibility for personnel and equipment, the slope of the ground, and location of drains (if any).
- provide fresh water supply and high pressure wash.
- provide cleaning agents as necessary.
- provide fork lifts and cranes for handling heavier equipment.
- provide floodlighting if 24 hours/day operation is envisaged.
- create sealed dike to prevent run-off and fit sump for pumpout.
- provide tanks or separators for water/oil separation.
- provide clean water run-off from separator to drain.
- provide container(s) for separated waste oil.

Once the washing facility is operational, the following procedures should be observed:

- wash dirty equipment using water only or special cleaning agents.
- pump oily water from dike to separator
- discharge separated water to drain and pump oil into storage container.

After the termination of clean-up operations all collected waste material (oil) should be removed to the waste disposal site/facility, and the site of washing facility should be restored to its original state.

As regards cleaning of **skimmers**, it might be possible to use high pressure hot water or steam or hydrocarbon solvents for oil removal, however dispersants and detergents should not be used on oleophilic skimmers (discs, drums, rope-mops). In order to retain their oleophilic properties, these can be cleaned with diesel oil.

Booms also need to be cleaned after use in spill response operations, in particular if they were in contact with oil. Booms that were used only for protection of a certain area and were not exposed to oil may only be washed with fresh water prior to storage. Oil contaminated booms will require more drastic cleaning methods, including the use of hot water, steam and dispersants. Whatever the cleaning method chosen, its compatibility with the boom material, according to the manufacturer's specifications, should be ensured prior to cleaning.

Chapter 14

INTERNATIONAL COMPENSATION MECHANISMS FOR DAMAGES CAUSED BY OIL POLLUTION

1. THE CONVENTION FRAMEWORK

The International regime of liability and compensation for oil pollution damage was devised in the aftermath of the "Torrey Canyon" incident in 1967. The liability of shipowners for oil spills from tankers was dealt with in the 1969 Civil Liability Convention (or CLC). This Convention laid down the principle of strict liability for shipowners, created a system of compulsory liability insurance and normally allows for the shipowner's liability to be limited on the basis of the size of the tanker. Supplementary compensation financed by levies on the oil receivers in Contracting States was established under the 1971 Fund Convention. The Fund Convention set up the International Oil Pollution Compensation Fund 1971 (1971 Fund) to administer the regime.

This so-called "old" regime of the 1969 and 1971 Conventions was amended in 1992 by two Protocols which came into force in May 1996. The amended Conventions are known as the 1992 Civil Liability Convention and the 1992 Fund Convention. The 1992 Fund Convention created a separate Organisation, known as the 1992 Fund.

2. COMPARISION OF THE “OLD” AND “NEW” REGIMES

The main differences between the "old" regime of the 1969 Civil Liability Convention and the 1971 Fund Convention and the "new" regime of the 1992 Conventions are set out below and are also summarized in Table I.

The 1969 and 1971 Conventions apply to pollution damage suffered in the territory (including the territorial sea) of a State Party to the respective Convention. Under the 1992 Conventions, however, the geographical scope is wider, with the cover extended to pollution damage caused in the exclusive economic zone (EEZ) or equivalent area of a State Party. A State which has not established an exclusive economic zone may determine that the Convention applies to an area beyond and adjacent to the territorial sea determined by that State in accordance with international law and extending not more than 200 nautical miles from the baselines from which the breadth of its territorial sea is measured.

The definition of pollution damage in the 1992 Conventions has the same basic wording as the definition in the original Conventions, but with the addition of a phrase to clarify that, for environmental damage (other than loss of profit from impairment of the environment), compensation is limited to costs incurred for reasonable measures actually undertaken or to be undertaken to reinstate the contaminated environment.

The 1969 Civil Liability Convention and the 1971 Fund Convention apply only to damage caused or measures taken after oil has escaped or been discharged. These Conventions do not apply to pure threat removal measures, i.e. preventive measures which are so successful that there is no actual spill of oil from the tanker involved. Under the 1992 Conventions, however, expenses incurred for preventive measures are recoverable even when no spill of oil occurs, provided that there was a grave and imminent threat of pollution damage.

Table 1. Comparison of "Old" and "New" regimes (as at November 1998)

	"Old" Regime		"New" Regime	
	1969 CLC	**1971 FC**	**1992 CLC**	**1992 FC**
SCOPE Geographical Pure threat-removal measures *Unladen tankers*	Territory including territorial sea. Not covered. Not covered.		Territory including territorial sea and EEZ or equivalent, if declared. Covered if grave imminent threat of pollution. Covered.	
SHIPOWNER'S LIABILITY Dependent on size of tanker Minimum for small ships Maximum liability	Yes None 14.0 million SDR (US$20 million)		Yes 3 million SDR (US$4 million) 59.7 million SDR **(US$83 million)**	
FUND'S COMPENSATION Maximum (including CLC)		60 million SDR **(US$84 million)**		135 million SDR **(US$189 million)**
INCREASING LIMITS	**Requires diplomatic conference**		**Simplified procedure established**	
ORGANISATION		1971 Fund		1992 Fund

The 1969 and 1971 Conventions apply only to ships which actually carry oil in bulk as cargo, i.e. generally laden tankers. Spills from tankers during ballast voyages are therefore not covered by these Conventions. The 1992 Conventions apply to spills from sea-going vessels constructed or adapted to carry oil in bulk as cargo i.e. laden and unladen tankers, including spills of bunker oil from such ships. Neither the 1969/1971 Conventions nor the 1992 Conventions apply to spills of bunker oil from ships other than tankers.

The limit of the shipowner's liability under the 1969 Civil Liability Convention is the lower of 133 Special Drawing Rights (SDR) (USD 186) per ton of the ship's tonnage or 14 million SDR (USD 20 million). Under the 1992 Civil Liability Convention, the limits are:

(a) for a ship exceeding 5 000 units of gross tonnage, 3 million SDR (USD 4 million);
(b) for a ship with a tonnage between 5 000 and 140 000 units of tonnage, 3 million SDR (USD 4 million) plus 420 SDR (USD 587) for each additional unit of tonnage; and
(c) for a ship of 140 000 units of tonnage or over, 59.7 million SDR (USD 83 million).

There is a simplified procedure under the 1992 Civil Liability Convention for increasing these limits.

Under the 1969 Civil Liability Convention, the shipowner is deprived of the right to limit his liability if the incident occurred as a result of the owner's personal fault (actual fault or privity). Under the 1992 Convention, however, the shipowner is deprived of this right only if it is proved that the pollution damage resulted from the shipowner's personal act or omission, committed with the intent to cause such damage, or recklessly and with knowledge that such damage would probably result.

Claims for pollution damage under the Civil Liability Conventions can be made only against the registered owner of the ship concerned. This does not preclude victims from claiming compensation outside the Conventions from persons other than the owner. However, the 1969 Civil Liability Convention prohibits claims against the servants or agents of the owner. The 1992 Civil Liability Convention prohibits not only claims against the servants or agents of the owner, but also claims against the pilot, the charterer (including a bareboat charterer), manager or operator of the ship, or any person carrying out salvage operations or taking preventive measures.

The compensation payable by the 1971 Fund in respect of an incident is limited to an aggregate amount of 60 million SDR* (USD 84 million), including the sum actually paid by the shipowner (or his insurer) under the 1969 Civil Liability Convention. The maximum amount payable by the 1992 Fund in respect of an incident is 135 million SDR (USD 189 million), including the sum actually paid by the shipowner (or his insurer) under the 1992 Civil Liability Convention. The 1992 Fund Convention provides a simplified procedure for increasing the maximum amount payable by the 1992 Fund.

Under the 1971 Fund Convention, the 1971 Fund indemnifies, under certain conditions, the shipowner for part of his liability pursuant to the 1969 Civil Liability Convention. There are no corresponding provisions in the 1992 Fund Convention.

In short, the 1992 Conventions provide much higher limits of compensation than the Conventions in their original versions and have a wider scope of application on several points.

The main improvements include:

- Special liability limit for owners of small vessels and substantial increase in limitation amounts;
- Increase in the limit of compensation payable by the IOPC Fund;
- A simplified procedure for increasing the limitation amounts;
- Extended geographical scope of application;
- Coverage of pollution from unladen tankers;
- Possibility to recover expenses incurred for preventive measures even when no spill of oil occurs, provided that there was a grave and imminent danger of pollution damage;
- New definition of pollution damage clarifying that, for environmental damage, only costs incurred for reasonable reinstatement measures are admissible.

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* *The unit of account in the 1992 Conventions is the Special Drawing Right (SDR) as defined by the International Monetary Fund. In this text, the SDR has been converted into US dollars (USD) at the rate of exchange applicable on 17 November 1998, i.e. 1 SDR = USD 1.39743.*

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3. STATUS OF CONVENTIONS

3.1 The "new" regime

When the 1992 Fund Convention entered into force on **30 May 1996**, nine States were Parties to the Convention and therefore Members of the 1992 Fund. Since then, the 1992 Fund Convention has entered into force for a further 18 States, bringing 1992 Fund membership to 27 in November 1998. In addition, 11 further States have deposited instruments of accession to the 1992 Fund Convention. By November 1999, the Convention will enter into force for these States, thus bringing the number of 1992 Fund Member States to 38.

The 1992 Civil Liability Convention is also in force for the two States which are not Parties to the 1992 Fund Convention.

The legislative process to implement the 1992 Conventions is in an advanced stage in a number of States. It is therefore expected that the 1992 Fund membership will continue growing.

3.2 The "old" regime

The membership of the 1971 Fund rose to a peak of 76 Member States in March 1998. On 15 May 1998 instruments of denunciation took effect in respect of 24 States which had become Members of the 1992 Fund, and the number of Sates fell to 52. By November 1999, instruments of denunciation of the 1971 Fund Convention will take effect for eight States, and therefore, the 1971 Fund will have only 44 Members.

With the denunciation of the 1971 Fund Convention by States which have become Members of the 1992 Fund, the total quantity of contributing oil on which contributions are paid has been reduced from its maximum of over 1200 million tonnes to its present level of 345 million tonnes. By November 1999, it will have fallen to some 250 million tonnes. The effects of this reduction in the contribution base is the considerably increased financial burden which might fall on the contributions in those States which remain Members of the 1970 Fund.

3.3 Overall picture

With the expected continuation of the above-mentioned trends, the 1971 Fund will soon have fewer members than the 1992 Fund. The relative number of Member states of the two Organizations is set out in Table II. The States of the Mediterranean fall into a number of different categories in terms of the Conventions, as illustrated in Table II.

With a view to assuring themselves of the availability of adequate compensation for oil pollution damage, the Mediterranean coastal States, who have not yet acceded to the 1992 Civil Liability and the Fund Conventions, are strongly encouraged to do so as soon as possible. The entry into force of the 1992 Conventions takes place 12 months after a State has deposited an instrument of ratification.

Table 2. Status of conventions (as at November 1998)

	"Old" Regime		"New" Regime	
	1969 CLC	**1971 FC**	**1992 CLC**	**1992 FC**
STATUS				
In force November 1998	76	52	30	27
Joining soon	1	0	10	11
Leaving soon	-8	-8	0	0
In force November 1999	**69**	**44**	**40**	**38**
MEDITERRANEAN STATES In force November 1998	As 1971 FC, plus Egypt and Lebanon	**Albania, Algeria, Croatia, Italy, Malta, Morocco, Slovenia, Syria, Yugoslavia**	As 1992 FC, plus Egypt	Cyprus, France, Greece, Monaco, Spain, Tunisia
Changes by November 1999		*Leaving:* Algeria, Croatia		*Joining:* Algeria, Croatia

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